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ANNOTATED BIBLIOGRAPHY OF APPLIED PHYSICAL ANTHROPOLOGY IN HUMAN ENGINEERING

ROBERT HANSEN
DOUGLAS Y. CORNOG

H. L. YOH COMPANY
PHILADELPHIA, PENNSYLVANIA

EDITED BY
H. T. E. HERTZBERG
AERO MEDICAL LABORATORY

MAY 1958

CONTRACT NO. AF 33(616)-2353

AERO MEDICAL LABORATORY
WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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FOREWORD

Numerous persons have contributed to the inception and completion of this volume. Mr. John W. Chaffee, at one time a member of the Anthropology Section, conceived the idea of a compendium of data in Biomechanics, purely for Section use, such reports being widely scattered and often in journals not easily obtained. The editor expanded the idea to include the whole field of Applied Physical Anthropology for which Anthropology Section is responsible. He monitored Contract AF 33(616)-2353, and later AF 33(616)-2845, with H.L. Yoh Company, Philadelphia, Pennsylvania, and critically reviewed the entire manuscript.

The editor is deeply grateful for the labors of all who participated. Messrs. Robert Hansen and Douglas Y. Cornog, and other members of the H.L. Yoh Company, who researched the literature and wrote the manuscript, deserve great credit for their work. The entire staff of Anthropology Section during this period also assisted in the project as they found time. Milton Alexander, Irvin Emanuel, Frank P. Saul and Capt. Franklin Van Wart, then a member of the Section, all took part in the reading of the rough-draft manuscript or assisting in the numerous administrative matters of the contract. James T. Barter spent nearly full time for several months in helping to guide the authors as they progressed. All made helpful suggestions that are incorporated in the final draft. Horace B. Clark spent many dedicated hours preparing illustrations and readying the manuscript for actual publication.

The text of this report has been carefully checked, and all tables have been double-checked. Nevertheless there must still be some mistakes. The editor will welcome any corrections or comments by the readers.

Many of the Air Force reports referenced in the bibliography are available to the general public at nominal cost from the Office of Technical Services, Department of Commerce, Washington 25, D.C.

ABSTRACT

This volume contains condensations of 121 reports in the field of Applied Physical Anthropology. A majority of the annotations are grouped under three headings, Anthropometry, Biomechanics, and Comfort; a few are included in a General Group. Working data and important illustrations are quoted directly from the original papers in most cases. A complete index is arranged by author as well as by subject. An additional list of reports (not annotated) is included as background material. Two appendices containing relevant commentary on Seating Comfort and Anthropomorphic Dummies, are also included.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

EDWARD L. COLE
Lt. Colonel, USAF
Asst. Chief, Aero Medical Laboratory
Directorate of Laboratories

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INTRODUCTION

H.T.E. Hertzberg

The fitting of tools to man has occupied designers to some degree since earliest times. These centuries of experience in custom fitting, however, have not hitherto produced organized body-size data for general use. Hence, in the modern proliferation of technology, the designer's need for accurate and up-to-date information on the human being appears more acute than ever before.

In today's technology, the concept of efficiency in machines has been vastly developed. Machines must not only run, they must show how well they are running. Thus instruments and other indicators of operational efficiency are considered essential in machines, and space is routinely provided for them. For easy interchangeability, components and assemblies are mass-produced to close tolerances. Finished machines of a given type roll off the production line, alike as pins, each highly effective for its purpose. This state, until recently, has been considered by many designers to be the last in their responsibility. But today we realize that every machine must somehow be teamed with a man; and the question now is, will each man-machine team operate at the peak efficiency of which the machine itself is capable?

The answer is: not necessarily. Although machines can be virtually identical, men are not, and their great diversity in dimensions and physical performance has not been charted nor even comprehended in a scientific sense until recent decades. But man, though highly variable, does vary between observable limits. Those limits, and the distributions of body size, proportions and strength, must be fully learned as a first step in raising the team potentiality to the level of the inherent efficiency of the machine itself.

The present report, accordingly, outlines some of what is known of the variations in body size (anthropometry), and of muscle strength and bodily structure (biomechanics) in the U.S. population; and it points out some means of decreasing man's discomfort and fatigue -- both important sources of human inefficiency.

Before proceeding to this task, however, it is well to sketch briefly the broader meanings of the terms introduced above. Anthropometry (the measurement of man) is the theory and practice of taking bodily dimensions by suitable instruments, and the orderly treatment of the resulting data. The practitioners of this science are usually specialists trained in the still wider field of Physical Anthropology (the study of man as an animal, including man's origins, his relations to other primates, and the differences in metrical and morphological traits among the living human varieties).

The term, Biomechanics, is used in the Air Force to denote the study of the human body as a dynamic solid. The muscle strength that a man can exert as a prime mover is an important part of this field. The mechanical properties of the body, such as the masses of bodily segments, the locations of centers of gravity of the segments and of the body as a whole, the mobility of segments -- all these and more are included. The data presented under this heading have been drawn from research in anatomy, anthropology, orthopedics, physiology, and other biological and medical sciences, for the use of designers.

When allowances have been made for both body size and muscle strength, will the resulting workplace be satisfactory? Many designers in the past have thought so, but experience teaches that yet another aspect of the man must be considered -- his comfort. To some persons the word comfort may imply a pleasurable state transcending normal well-being; but that state is unusual and it will be neglected here. For ordinary Air Force purposes the term comfort may be defined simply as the absence of discomfort, just as cold is the absence of heat. The study of comfort, still in its infancy, is a study of elusive subjective factors, which may be made reasonably objective by statistical treatment. It is a field that is becoming increasingly important as personal equipment becomes heavier and covers more of the body, and must be worn for longer periods of time. The numerous factors that may cause compressional discomfort cannot be discussed now, but two important principles can be stated here:

1. the length of time that a sampling of subjects can endure a given body condition is, up to now, the simplest measure of the degree of discomfort it causes them;

2. an uncomfortable man tires, and hence becomes inefficient, more rapidly than a comfortable one.

In some circumstances, the degree of discomfort may spell the difference between life and death. At least in aircraft, human inefficiency from any cause is too costly in machines and highly-trained men to be tolerated. It is important to discover and eliminate the sources of discomfort in aircraft; but even much ground equipment design -- such as many types of vehicular seats and work areas -- may well receive additional attention.

This report has been compiled to call attention to some of the data available for application to problems of design. A major difficulty lay in the choice of what to include. The authors amassed a bibliography of about a thousand titles, from which this material (probably less than 10% of the literature) was chosen primarily according to its usefulness in helping solve Anthropology Section problems. Some major works, however, have been annotated either briefly or not at all, because of the very breadth of their coverage, or for other reasons.

GENERAL

1. Damon, Albert, and Francis E. Randall. Physical Anthropology in the Army Air Forces. American Journal of Physical Anthropology, New Series, Volume 2, Number 3, September 1944, pages 293-316.

This article describes in general terms the anthropology program of the Army Air Forces conducted at the Aero Medical Laboratory, Wright Field, Dayton, Ohio in 1943 and 1944. The history of the military applications of the discipline is briefly indicated. The conduct of body size studies and other surveys is described. The final sections of the article are devoted to a consideration of applications of anthropometric data to a wide variety of problems of military aviation.

The article is 23 pages long. There are three figures. Three bibliographic references are given.

2. Hertzberg, H.T.E. and Gilbert S. Daniels. Air Force Anthropology in 1950. American Journal of Physical Anthropology, Volume 10, New Series, Number 2, June 1952, pages 201-208.

The article reports certain activities of the Anthropology Unit of the Aero Medical Laboratory at Wright-Patterson Air Force Base in 1950 in carrying out its responsibility to provide information on human dimensions, human muscle strength, and human comfort. In the dimensional field, the conduct of the Anthropometric Survey was the main activity, the survey being based on flying personnel (N = 4050), 132 measurements and four somatotype photographs being obtained on each. In the field of human strength measurement, one problem investigated was to determine not only the strength of pilots but also the most efficient angle at which the muscle force could be applied in the cockpit in operating foot pedals. The study of human comfort involved projects on "the prone position bed for pilots, the supine seat for pilots, and the control stick grip development for fighter airplanes." Future plans of the Unit include basic research on the body as a mechanical structure. The article encourages young men to consider the field as a life work and emphasizes the need for heads of academic departments to see the applied aspects of anthropological research in a favorable light.

The paper is seven pages long including two photographs and three bibliographic references. There are no tables, figures, or data.

Additional reference: Hertzberg, H.T.E. Post War Anthropometry in the Air Force. American Journal of Physical Anthropology, New Series, Volume 6, Number 3, September 1948, pages 363-371.

3. King, Barry G. Measurements of Man for Making Machinery. American Journal of Physical Anthropology, New Series, Volume 6, Number 3, September 1948, pages 341-351.

This article deals with the relation of the biologist to the engineer. "Biotechnology" can supply the engineer with quantitative descriptions of man such as:

"1. The maximum arm reaches which can be attained by man without altering his position or posture. These measurements constitute a reasonable basis for establishing the maximum boundaries of the working area for the operation of manual controls.

Manuscript submitted by the authors in September 1956 for publication as a WADC Technical Report.

"2. The extension of these reaches which can be attained by movements of the trunk or body. Knowledge of such measurements may be required for special cases in new design, or for formulation of expedient measures in current models where the possibility of structural change is precluded.

"3. The eye level of men in the operating position.

"4. Dimensions of the body in the operating position, i.e., stature or sitting height, and antero-posterior and lateral measurements at various levels.

"5. The leg reaches which can be attained without altering the position of the body or disrupting body posture.

"6. The direction and degree of movement of the various articulations which can be utilized for the operation of controls at a biomechanical advantage to apply the necessary force efficiently and to attain the necessary degree of precision of movement.

"7. The position of the body to minimize distracting discomfort."

The author discusses the applications of such information to problems of cockpit design.

The article is 10 pages long, containing two tables shown here, three figures, and a four-item bibliography.

See also: King, Barry G., Dorothy J. Morrow, and Erwin P. Vollmer. Cockpit Studies -- The Boundaries of the Maximum Area for the Operation of Manual Controls. Report No. 3, Project X-651, Naval Medical Research Institute, National Naval Medical Center, Bethesda, Maryland, 15 July 1947.

TABLE 3 - 1

The maximum distance (inches) at various points in the boundary area for operation of manual controls which can be reached by 97.73% of the population at each position and 92.9% of the NMRI series at every position; N = 139 (From King, Morrow and Vollmer, '47)

LEVEL (INCHES) ABOVE SEAT REFERENCE POINT	ANGLE (DEGREES)			
	0	R15	R45	R75
46	11.6	13.7	15.0	17.0
40	18.9	20.5	22.4	24.1
34	22.9	24.9	26.6	28.0
28	25.5	27.1	29.1	30.1
22	26.7	28.2	30.3	31.4
16	26.6	28.0	29.7	31.6
10	25.3	27.0	29.3	30.4
4	22.6	24.2	26.4	27.9
—2	17.5	19.7	21.8	22.8

Note: Distances for right arm reach are measured from the vertical line through the reference point with the subjects' shoulders touching the back cushion; seat back 13 degrees from the vertical. R15° stands for 15 degrees to right. Reach for left arm can be outlined by using above measurements at corresponding points to the left of 0 degrees.

TABLE 3 - 2

Location of aircraft controls in the Martin 202; extension of shoulder harness required for a particular pilot to reach controls

AREA AND CONTROL	DISTANCE FROM REFERENCE POINT [1] Horizontal	DISTANCE FROM REFERENCE POINT [1] Vertical	DEGREES RIGHT OR LEFT [2]	EXTENSION FOR SHOULDER HARNESS REQUIRED FOR MOVEMENT OF PILOT "SMI" [3]
	inches	*inches*		*inches*
Area 2. Control pedestal — upper half				
Right tank selector	42	+ 6	R-33	15¼
Ignition	39½	+ 5	R-27	13½
Over-ride	44½	+ 5	R-35	16¼
Area 3. Control pedestal — lower half				
Aileron trim tab.	24½	— 4	R-72	0
Area 4. Main instrument panel				
Altimeter set	38	+ 13½	R-4	9¼
Selector valve for air speed	38	+ 9¾	R-3	9½
Area 5. Instrument panel — upper portion				
Windshield wiper	42½	+ 23½	R-20	12¾
Instrument lights	40	+ 23½	R-31	9
Area 6. Overhead instrument and switch panel				
Emergency shut-off fuel, oil, hyd. to rt. eng.	34¾	+ 38½	R-60	10
Area 7. Side control panel				
Mike selector	36	+ 6½	L-15	9¼
Trans. selector switches	36	+ 4½	L-15	8¾

[1] Pilot seat at mid-horizontal and mid-ventral adjustment.
[2] Midline of pilot's body (midsagittal section) at zero degrees.
[3] This pilot's arm length is indicated by his sleeve length: 32 inches.

4. Le Gros Clark, W.E. Physical Anthropology Applied to Problems of War. British Medical Journal, Volume I, 12 January 1946, p. 39.

The need for "fitting the machine to the man" is discussed with especial reference to war conditions and the personnel who did this type of work in Great Britain. The application examples include location of optical instrument eye-pieces and seat design. The seat design requirements are noted as: "(1) It must allow the operator to maintain a sitting position for periods of duty up to four hours without undue discomfort and fatigue. (2) It must permit maximum stabilization of the body while keeping the arms free to manipulate handcontrols and without restricting the mobility of the neck and upper part of the spine for sighting movements. (3) The seat level must be adjustable in relation to both the level of the binoculars and the level of the foot-rest, so as to accommodate individuals of different body dimensions. (4) It must combine lightness with mechanical strength. (5) It must stand up to very severe usage and be weatherproof." The article notes that "...there is no doubt that the ideal seat should be flat, but covered by padding which has a degree of elasticity sufficient to distribute the weight of the body over as wide an area as possible surrounding the ischial tuberosities while at the same time allowing the maximum pressure to remain concentrated over the tuberosities themselves." The back-rest "must provide support for the upper part of the trunk (taking some of the weight of the body in the relaxed position), it must be accurately placed so that counter-pressure from the feet in body stabilization can be most effectively maintained, and it must allow free mobility to the thoracic and cervical spine." The rest should be pivoted, must accommodate the wide back and the individual in heavy arctic clothing. Body stability is essential for accurate work.

"The research organizations developed during the war for the study of anatomical and related problems have proved their worth by the fact that in a comparatively short space of time they have led to quite a number of significant advances in practical and theoretical knowledge. But the continuance of research in peace-time at the rate and rhythm which it manifested in the last war depends on several factors. It depends on the availability of research personnel of high calibre, imbued with a community spirit comparable with that which characterized the research worker of the war, on financial support of the most generous kind, and on a directorate which not only ensures adequate coordination of workers in widely different fields of science but is also capable of supplying the inspiration necessary for successful team-work."

This article is four pages long. There is no bibliography and no figures or tables are given.

5. Mayo, A.M. Designing the Cockpit to the Man. American Aviation, Volume 17, No. 3, 6 July 1953, pp. 23-26 and No. 4, 20 July 1953, pp. 48-53.

This article discusses the various aspects of aircraft design where "Increased ingenuity must compensate for human limitations, now the weak link in the aircraft design chain." Subjects noted include: (cockpit) size, data presentation, control systems, personal equipment, protective clothing, vision problems, acceleration and temperature, noise and vibration, radiation, meteorites, control of forces, especially as related to escape systems.

The six illustrations include a graph of pilot endurance of acceleration, a chart of human reaction time in relation to high aircraft speeds, a chart of pilot bail out limits and charts of meteorite penetration factors and probability of being struck by meteorites. The article presents little data, other than that in the charts and graphs, and no source references or bibliography. The articles are noted as being "the first portion of a paper entitled 'Engineering the Cockpit to Man,' presented at a recent symposium on 'Frontiers of Man-Controlled Flight' under the auspices of the University of California and The Institute of Aeronautical Sciences by A.M. Mayo of Douglas Aircraft Co."

6. McFarland, Ross A., Albert Damon, Howard W. Stoudt, Alfred L. Moseley, Jack W. Dunlap, and William A. Hall. Human Body Size and Capabilities in the Design and Operations of Vehicular Equipment. Boston: Harvard School of Public Health, 1953, 239 pages.

"This manual is intended to assist the design engineer in understanding the wide range of human variables involved in the operation of different types of vehicular equipment. It is also intended to acquaint the biological scientist with the sort of engineering problems that often arise in the field of equipment design. An effective integration of men and machines, with a consequent increase in safety, can only be achieved if there is a common understanding of the human requirements and operational problems involved in the design of equipment. With this aim in view the principles of human engineering are outlined as they apply to the design of many types of vehicles, including armored vehicles and aircraft. Pertinent studies are reviewed from the applied fields of psychology, physiology, and anthropology. Of singular importance is the presentation, for the first time, of original data on the range of body size of commercial truck and bus drivers, as well as operators of military equipment. These data are in the form of percentile distribution tables which enable the engineer to design for the accommodation of any desired percentage of the population. This manual should be of interest to engineering, safety, and medical personnel, and should enable them to guide and evaluate the design of vehicles in terms of the operator's safety, health, and efficiency.

"The major sections of the report include: I, The Problem, with a discussion of the role of accidental trauma as well as the medical and operational implications of deficient design; II, The Approach, including basic data on human capabilities; III, The Job, an analysis of job requirements, including the design of controls, displays, working areas and seats; IV, The Machine, presenting design studies and evaluations in trucks, buses, tractors, tanks, and aircraft; and V, General Principles of man-machine integration."

The basic premise is that, in order to achieve maximum efficiency of any machine system involving a human operator, the significant dimensions, abilities, and limitations of the operators must be considered equally with engineering factors from the initial design to the final construction.

Statistical evidence and specific examples are given to show that failure to adequately evaluate and allow for the relationship of the operator to the machine result in seriously reduced efficiency of both machine and operator, unnecessarily high accident rates, and loss of time and money.

TABLE 5 - 1

Percentile Distribution of Body Dimensions: Army and Civilian Drivers

Dimension	Group	N	Range	Median	Percentile 5	50	95
Age	Civilian Drivers	310	20 - 64	36.27	25.00	36.27	48.46
(Years)	Army Drivers	2380	15 - 43	22.44	19.49	22.44	32.30
Stature	Civilian Drivers	306	62.11- 75.47	68.35	64.64	68.35	72.48
	Army Drivers	2380	60.24- 77.56	68.23	64.21	68.23	72.50
Weight	Civilian Drivers	305	110 -300	163.74	129.00	163.74	212.82
(pounds)	Army Drivers	2380	100 -271	153.10	126.52	153.10	191.67
Total Span	Civilian Drivers	305	62.89- 77.83	70.87	66.46	70.87	75.47
	- - - - -	—	- - - - -	—	—	—	—
Anterior Arm Reach	Civilian Drivers	312	30.66- 41.67	35.75	32.95	35.75	38.42
	- - - - -	—	- - - - -	—	—	—	—
Span Akimbo	Civilian Drivers	310	31.45- 42.45	36.61	34.09	36.61	39.21
	- - - - -	—	- - - - -	—	—	—	—
Head Height	Civilian Drivers	315	4.48- 5.74	5.12	4.68	5.12	5.47
Left	Army Drivers	1664	4.41- 5.91	5.15	4.81	5.15	5.56
Shoulder Breadth	Civilian Drivers	310	14.94- 21.62	18.34	16.92	18.34	19.90
	Army Drivers	2373	14.96- 22.05	17.92	16.56	17.92	19.66
Chest Breadth	Civilian Drivers	311	9.04- 14.94	11.79	10.16	11.79	13.47
	Army Drivers	1652	8.27- 15.35	11.12	9.99	11.12	12.41
Chest Depth	Civilian Drivers	312	6.29- 12.97	8.86	7.58	8.86	10.48
	Army Drivers	1662	5.91- 11.81	8.31	7.27	8.31	9.58
Hip	Civilian Drivers	313	9.04- 14.94	11.72	10.71	11.72	13.12
Breadth	Army Drivers	1656	8.66- 15.35	11.42	10.28	11.42	12.90
Foot	Civilian Drivers	293	8.25- 12.18	10.43	9.60	10.43	11.32
Length	Army Drivers	2359	9.09- 11.69	10.44	9.65	10.44	11.23
Foot	Civilian Drivers	312	3.38- 4.80	3.98	3.68	3.98	4.32
Breadth	Army Drivers	2369	3.07- 4.69	3.89	3.50	3.89	4.27
Head	Civilian Drivers	313	20.83- 23.98	22.34	21.40	22.34	23.44
Circumference	Army Drivers	2376	19.69- 24.80	22.26	21.28	22.26	23.33
Chest	Civilian Drivers	311	31.45- 51.10	38.31	34.13	38.31	44.18
Circumference	Army Drivers	2375	29.53- 46.46	36.31	33.05	36.31	40.48
Abdominal	Civilian Drivers	311	6.68- 13.76	9.50	7.84	9.50	12.06
Depth	Army Drivers	1665	6.69- 13.78	9.03	7.97	9.03	10.51
Right Calf Circumference	Civilian Drivers	305	11.40- 20.05	14.15	12.60	14.15	16.04
	- - - - -	—	- - - - -	—	—	—	—
Left Calf	Civilian Drivers	313	9.45- 20.87	14.09	12.60	14.09	16.06
Circumference	Army Drivers	1207	11.42- 17.76	14.04	12.55	14.04	15.62
Erect Sitting	Civilian Drivers	310	33.07- 39.00	36.34	34.33	36.34	38.19
Height	Army Drivers	2639	30.71- 41.34	35.70	33.46	35.70	37.85
Normal Sitting Height	Civilian Drivers	313	30.71- 37.80	34.65	32.60	34.65	36.58
	- - - - -	—	- - - - -	—	—	—	—
Trunk Height	Civilian Drivers	311	20.47- 26.38	23.66	22.01	23.66	25.24
	Army Drivers	1671	18.50- 26.38	22.96	20.92	22.96	24.92
Buttock-Knee	Civilian Drivers	310	21.26- 27.56	23.78	22.05	23.78	25.79
	Army Drivers	2353	19.29- 27.56	23.33	21.49	23.33	25.16
Knee Height	Civilian Drivers	301	19.29- 25.98	21.69	20.08	21.69	23.50
	Army Drivers	2376	17.72- 25.59	21.56	19.78	21.56	23.42
Elbow Breadth	Civilian Drivers	282	12.99- 24.41	17.52	14.88	17.52	20.71
	Army Drivers	1664	13.39- 23.62	17.48	15.35	17.48	20.25
Seat Breadth	Civilian Drivers	308	11.42- 20.08	14.49	13.15	14.49	16.34
	Army Drivers	1656	11.42- 18.90	13.84	12.65	13.84	15.37
Knee Breadth	Civilian Drivers	311	6.69- 11.02	8.07	7.32	8.07	9.17
	- - - - -	—	- - - - -	—	—	—	—
Shoulder-Elbow	Civilian Drivers	311	12.60- 16.39	14.80	13.78	14.80	15.87
Height	Army Drivers	1650	11.42- 16.54	14.26	13.01	14.26	15.49
Elbow-Middle	Civilian Drivers	311	15.75- 22.05	18.82	17.32	18.82	20.20
Finger	Army Drivers	1636	14.96- 22.05	18.72	17.17	18.72	20.07
Hand Length	Civilian Drivers	314	6.54- 8.58	7.60	7.09	7.60	8.11
	Army Drivers	2364	6.61- 8.82	7.60	7.02	7.60	8.19
Hand Breadth	Civilian Drivers	311	2.99- 4.02	3.47	3.19	3.47	3.82
	Army Drivers	2372	2.76- 4.17	3.46	3.17	3.46	3.75
Hand Circumference	Civilian Drivers	311	7.16- 9.53	8.27	7.56	8.27	8.90
	- - - - -	—	- - - - -	—	—	—	—
Normal Sitting Eye Height	Civilian Drivers	309	26.38- 32.68	29.61	27.72	29.61	31.61
	- - - - -	—	- - - - -	—	—	—	—

Note: Dimensions are in inches, unless otherwise noted.

Effects of environmental factors such as temperature, humidity, ventilation, noise, and vibration are discussed, and pertinent research data cited. A survey of human engineering accomplishments in the fields of aircraft, tanks, tractors, railways, and industry in general is presented, with emphasis on the methods by which the data were gathered. A description is given of the use of adjustable mockups.

Specific requirements of the operator space in a vehicle, such as adequate range of visibility and seat design, are given. A sample check list and a critical evaluation of the human factors in the design of a widely used truck are included.

Appendices include a description of anthropometric instruments, data obtained with such equipment, methods of taking the measurements, percentile distribution tables of 32 functional body dimensions, and seven tables showing the correlations between the various body dimensions.

Since this is a manual compiled through a detailed analysis of 117 references, it is beyond the scope of an annotation to include the individual data and recommendations. "The manual consists of 239 pages including 46 illustrations, 50 tables, a bibliography of 117 items, and an index."

7. McFarland, Ross A. and Alfred L. Moseley. Human Factors in Highway Transport Safety. Harvard School of Public Health, Boston, 1954.

"In this research program which has been undertaken in the field of Highway Transport Safety, four separate studies have now been completed. The subject matter of the present, or third, study has been divided into five major areas... . The introductory section...gives a brief outline of the importance of accidents in general, and of highway accidents in particular. The various approaches for the reduction of accidents in the truck and bus industries are also presented." ...The remaining sections deal with such matters as the selection of drivers, human maintenance, human factors in the design of equipment, and operating procedures and accidents. "The original research findings from this investigation on highway transport safety have been integrated with previously published studies throughout the report. A selected bibliography is given at the end of each chapter for reference purposes. A glossary of terms frequently used in the highway transport industry and in the biological sciences, as well as a general topical index, are included at the end of the report.

Chapters 8 and 9 deal with the physical anthropological aspects of equipment design and workspaces.

The report is 295 pages long. It contains 65 tables and 73 figures. The bibliographies total 338 references.

See also: McFarland, Ross A., Albert Damon, Howard W. Stoudt, Alfred L. Moseley, Jack W. Dunlap, and William A. Hall. Human Body Size and Capabilities in the Design and Operations of Vehicular Equipment. Boston: Harvard School of Public Health, 1953, 239 pages.

McFarland, Ross A., Jack W. Dunlap, William A. Hall, and Alfred L. Moseley. Human Factors in the Design of Highway Transport Equipment. Boston: Harvard School of Public Health, 1953, 88 pages.

King, Barry G., Dorothy J. Morrow, and Erwin P. Vollmer. Cockpit Studies --The Boundaries of the Maximum Area for the Operation of Manual Controls. Report No. 3, Project X-651, Naval Medical Research Institute, National Naval Medical Center. Bethesda, Maryland, 15 July 1947.

Randall, Francis E., Albert Damon, Robert S. Benton, Donald I. Patt. Human Body Size in Military Aircraft and Personal Equipment. Army Air Forces Technical Report No. 5501, Air Materiel Command, Dayton, Ohio, 10 June 1946.

Statistical data on human body size, in the form of percentage tables, are presented, based on 2,500 Army drivers "sorted from a sample of 25,000 soldiers measured by the Quartermaster Corps at time of demobilization" after World War II, and 360 civilian bus and truck drivers. From these tables it is possible to determine what percentage of a population will fit any specified operational dimension of a machine, such as distance to a control knob or foot pedal. Of equal importance for vehicle or machine design is the information presented on human capabilities, i.e., reaction time, speed and strength of arm and leg movements and range of motion of the joints of the body.

8. McFarland, Ross A., Jack W. Dunlap, William A. Hall, and Alfred L. Moseley. Human Factors in the Design of Highway Transport Equipment. Boston: Harvard School of Public Health, 1953, 88 pages.

A summary of the findings arrived at by application of human engineering principles to the evaluation of representative trucks widely used in both civilian and military transport. Trucks evaluated are identified by research team's code number - manufacturer and actual model number are not given. The primary objective has been to improve safety and efficiency in operating all types of vehicular equipment. Twelve different models were evaluated.

Factor	Range	Number Deficient	Specific Deficiencies	Recommendations
Cab space	---	4	short fore and aft (2) dash board overhang (1) inadequate head room (1)	-----
Seat height above floor	12 1/2 - 18 1/2"	---	no agreement on best height	standardization based on scientific body measurement
Seat width	17 1/2 - 55"	0		
Seat depth	16 - 20 1/2"	0		
Height of seat back	17 1/4 - 21"	0	------	all considered adequate for driver
Width of seat back	17 1/2 - 70"	0		
Vertical seat adjustability	0-3"	12	adjustability insufficient or non-existent (9)	4-5" adjustability
Horizontal seat adjustability	0-5"	11	adjustability insufficient or non-existent (2)	5" of adjustability
Steering wheel	one wheel adjustable 2"	11	adjustability non-existent	make all wheels adjustable
Directional signal	-----	12	non-existent (5) too far from wheel, non-self-canceling (7)	self canceling finger-tip control, not more than 2 1/2" from rim of steering wheel
Gear shift	length of lever arm 23" - 29"	---	-----	none
Hand brake	----	5	12 require 125 lbs. release pressure, 5 have push-button which may require both hands to release	should be standardized as to position, for one-hand release at pressures not to exceed 90 lbs. for right hand, 80 lbs. for left
Dimmer switch	standardized most on left side of steering post	1	located at base of steering post	-----
Clutch pedal width	3" - 5 1/2"	5	pedal too narrow	4" - 4 3/4"
angle	0-80 degrees	---	-----	should be standardized at scientifically arrived-at angle
surface	-----	5	steel surface	rubber surface

Factor	Range	Number Deficient	Specific Deficiencies	Recommendations
Brake pedal	-----	---	deficiencies and recommendations concerning width, angle, and surface are the same as for the clutch pedal	
height above floor	8 1/4" - 10 1/2"	5	pedal too high	minimum possible height
Accelerator	-----	---	------	at least 2 1/2" separate from other pedals
pedal angle at cruising speed	not determined	---	------	should be standardized at best angle
Air horn control	-----	12	no air horn (7) overhead pullcord or chain (5)	should be foot control near dimmer switch
Front brake control	-----	2	out of normal reach	standardized location within normal reach
High-low range shift control	------	3	located on dash or floor	standardize on shift lever
Starter control	-----	3	foot operated	hand operated on dash
Windshield wiper	-----	10	two dead turns in switch, single speed vacuum (air) operated	instant starting variable speed electric
Windshield divided-single panel	-----	5	divided windshield	single panel
curved-flat	-----	3	curved windshield	flat
area	504 - 1080 sq. in.	12	inadequate visibility up and down	vertical dimensions should be increased
windshield cleaning, outside (wiper coverage)	39 - 63%	12	limited visibility in poor weather	greater coverage
inside (de-fogging, de-frosting)	-----	12	no form of de-fogging	de-fogging system recommended
Instrument panel				
general arrangement and location	-----	---	no standardization several panels in center of cab	should be located directly in front of driver - instruments arranged and sized in accordance with importance of each
Dial colors	-----	4	green on brown tan on cream yellow on brown black on cream	white figures, black background
night illumination	-----	---	not mentioned	red or violet

Factor	Range	Number Deficient	Specific Deficiencies	Recommendations
Dial design recommendations 1. Best size of round dials for reading at about 28 inches is approximately 2 3/4 inches diameter. 2. Open-window type dial (direct reading counter) is best for rapid reading. 3. Fewest possible markings. 4. Dial scale increasing from zero to higher readings clockwise, or up for increase, down for decrease. 5. Numbered marks about 1/2 inch apart. 6. Consistent space between dial marks. 7. All dials indicating increase rotate in same direction. 8. Dials using metric system can be read most accurately. Avoid non-linear scales. 9. Avoid use of decimal point where possible; omit zero before decimal point. 10. Scales should be increased by units which are numbered 1,2,3,4, or 10,20,30, 40, etc., and marks can usually best be placed at 0,5,10,15, etc. 11. There should be a gap or break between beginning and end of scale. 12. Groups of dials should be patterned so that all "correct" readings are oriented in same direction, so as to make malfunction readable at a glance.				
Anterior arm reach	-----	12	not taken into consideration in any vehicles	should be factor in design, based on measurement data already available
Knee height	-----	12	all vehicles discommoded at least 15% (70% in one) of driver population	same recommendation as above (brake pedal-steering wheel distance especially important) adjustable steering wheel, greater fore-and-aft seat adjustability recommended
Foot length and breadth	-----	12	brake pedals too small; men with long feet tend to scrape toes against firewall; when operating brake or clutch catch feet on pedals	make brake pedal larger; move accelerator to right; move firewall forward; allow more room between all foot controls; install throttle on panel
Hand length	-----	---	turn indicator and trolley brake cannot be operated without removing hand from wheel	rarely critical; turn indicator and trolley brake should be reachable without removing hands from wheel
Buttock-knee distance	-----	---	approximately 20% of taller drivers strike right knee on trolley brake valve assembly when operating foot brake. 15% find dash board too close to knee	fairly well provided for; greater clearance between floor and dash and between floor and trolley brake valve assembly

Factor	Range	Number Deficient	Specific Deficiencies	Recommendations
Abdomen depth	-----	---	stoutest 20% of drivers find steering wheel seat clearance inadequate	generally adequate
Knee length	-----	---	right knee of 50% of drivers touches gear shift occasionally--taller men knock left knee on vertical hand brake	move gear shift to right; move hand brake
Noise level		---	interference with normal speech (50-75 db.)	damping in engine enclosure; better muffler design
idling	46 - 89 db.			
2nd and 3rd gear	80 - 95 db.			
4th gear	just below 90 db.			
Relative humidity (measured with a "Hand-Operated Psychrometer" in closed cab after heater had been on full for 15 minutes	23-78% (outside humidity 27-71%) change of humidity ranged from an increase of 32% to a decrease of 10%	---	------	------
Temperature	-----	---	------	best temperature range 60 to 84 degrees F; air conditioning recommended for areas having extreme high temperatures
Vibration	------	---	in many instances seat accelerates existing vibration	isolate driver from engine and chassis vibrations at operator's seat
Ventilation	-----	---	toxic levels of carbon monoxide found in several models after 15 minutes idling with cab closed	further study required
Seat comfort	-----	---	------	more research in seat design with specific reference to drivers' seats
Changing of body position	-----	---	lack of adequate lateral space; 3 vehicles' space too small for 50% of population	rearrangement of existing structures to allow more space
Safety factors	-----	---	------	provide driver and passengers with shoulder harnesses
Safety equipment	-----	---	------	standardize location in one place

Factor	Range	Number Deficient	Specific Deficiencies	Recommendations
Emergency escape	-----	8	noted as difficult to escape from	make windows large enough for largest man to escape through

The figures in parentheses under column four, Specific Deficiencies, denote the number of occurrences of the specific deficiency, where appropriate.

Appendix material includes a list of 25 selected references directly related to the field of investigation, 26 tables listing specific data for each truck model in the characteristics investigated, and scale drawings of the cab area of 10 of the 12 vehicles studied.

See also: McFarland, Ross A., Albert Damon, Howard W. Stoudt, Alfred L. Moseley, Jack W. Dunlap, and William A. Hall. Human Body Size and Capabilities in the Design and Operations of Vehicular Equipment. Boston: Harvard School of Public Health, 1953, 239 pages.

9. Morant, G.M. Applied Physical Anthropology in Great Britain in Recent Years. American Journal of Physical Anthropology, New Series, Volume 6, Number 3, September 1948, pages 329-339.

The author describes the applied physical anthropological studies carried out in England. "In recent years research of this kind carried out in Great Britain has been concerned chiefly with the application of the techniques, methods of treatment, and records regarding morphological measurements of the body to particular practical problems. These have been personnel problems of the fighting forces concerning relations between groups of men and the spaces in which they work, or the clothes they wear.

"During the war, body measurements were recorded for nearly 3000 Royal Air Force flying personnel and 2200 Royal Armored Corps personnel. Body measurements of children, in a survey in progress regarding seating carried out by the Department of Anatomy of the University of Birmingham...have been obtained."

The author stresses the need for empirical trials in evaluating clothing and equipment prototypes originally designed on the basis of anthropometric studies. He also emphasizes that, for the work of the anthropologist to be useful, it must be sold to those in a position to implement it.

The article is 10 pages long. There are no tables or figures. A bibliography of 12 items is included.

Additional references: Keith, Arthur. Problems of British Anthropology. Journal of the American Medical Association, Volume 70, No. 14, 6 April 1918, pp. 1020.
Morant, G.M. Anthropometric Problems in the Royal Air Force. British Medical Bulletin, Volume 5, Number 1, 1947.

10. Newman, Russell W. Applied Anthropometry. In Anthropology Today, an Encyclopedic Inventory prepared under the Chairmanship of A.L. Kroeber, The University of Chicago Press, Chicago, Illinois, 1953, pages 741-749.

The author describes ways in which anthropometry has been applied to the solution of industrial and military problems. The study conducted by the United States Department of Agriculture to provide accurate data pertinent to the sizing of young people's clothes is discussed. The term "Commercial Standard" is defined and its implications analyzed. The determination of the space requirements for various kinds of work is considered to be a field of limitless research possibilities. The last half of the article concerns itself with an examination of specific strengths and weaknesses which anthropometry brings to such problems as the determination of clothing sizes and workspace requirements.

The article is eight pages long. There are no tables, figures, or data. The bibliography lists seven references.

11. Randall, F.E. Anthropometry in the Quartermaster Corps. American Journal of Physical Anthropology, New Series, Volume 6, Number 3, September 1948, pages 373-380.

This article describes the applications of physical anthropology that have been made in the Army. "The application phases fall into 2 main categories. The first is to a great extent, pure anthropometry in that it is concerned with the measurement of human beings in considerable detail. The collection of large series of detailed measurements is considered to be of primary value in that the data, when analyzed, will serve to provide a constant source of reliable information upon which further studies may be based. The second phase falls into the category of testing. In this phase, anthropometry is highly specialized, in that small numbers of dimensions are taken and quite frequently taken on limited series of individuals which are subsequently evaluated in terms of the initial large series."

The author gives several examples of these two different types of anthropometry as found in the Quartermaster Corps research program. Figures are supplied on the following topics: (1) the kinds of sociological background data collected, (2) the particular physical measurements taken, (3) frequency distributions of stature and weight, (4) dimensional changes throughout a population by changes in stature and weight, (5) overall variations in the population, and (6) a chart for a proposed procedure of the Quartermaster Corps.

The article is seven pages long containing six figures and a bibliography of five references.

12. Randall, Francis E., Albert Damon, Robert S. Benton, Donald I. Patt. Human Body Size in Military Aircraft and Personal Equipment. Army Air Forces Technical Report No. 5501, Air Materiel Command, Dayton, Ohio, 10 June 1946.

"The present report deals with the relation of human body size to military aircraft and equipment. It contains the necessary data and instructional material to guide the designers of aircraft and associated flying equipment in the proper use of anthropometry, as it applies to AAF flying personnel. The functional man is fully described and the spatial requirements of his personal equipment are evaluated. Finally, the complete functional man is considered in his air crew position and as an integral part of the functional aircraft."

The report is 333 pages long and contains a large number of figures, photographs, and tables. The bibliography lists 75 references. For selected portions of the data, see also: Ashe, William F., Paul Bodenman, and Lester B. Roberts. Anthropometric Measurements. Project No. 9, File No. 741-3, Armored Force Medical Research Laboratory, Fort Knox, Kentucky, 1 February 1943.
Randall, Francis E. Seat Comfort. Paper No. 46-F-11 (M971-'46) for presentation at the Fall Meeting of the American Society of Mechanical Engineers, Boston, Massachusetts, 30 September - 3 October 1946.

13. Schroeder, Francis de N. Anatomy for Interior Designers. Second Edition, New York: Whitney Publications, Inc., (18 East 50th Street, New York 22), 1951.

Graphic sizing standards are presented for the design of home and commercial furniture, interiors and equipment relations in terms of human-use requirements. Basic measurements are based on the "...average man and woman (he's 5 feet, nine inches high, and she's 5 feet, 8 inches)." As the sources of this data, the author notes that they "...have gone to designers, architectural reference books, and in one or two cases to life insurance statistics, to present our own table of standards."

Subjects covered include: stairs and passageways, the business office, bars and restaurants, the living room, the game room, storage space (masculine and feminine), and the human eye and television. The approach has been to follow "...our average man and woman...through an average day."

The book contains 96 pages, which are primarily dimension illustrations with a minimum of text and no bibliography.

Additional reference: Freese, Ernest I. The Geometry of the Human Figure. American Architect, Volume 144, July 1934, pp. 57-60.

Editor's note: This summary is included here for the sake of completeness. The data have been used by many architects and builders in recent years, and thus affect the lives of a large segment of the population. It must be pointed out, however, that the body dimensions have been gathered from a sample of unknown size, by unknown measurers and by unknown techniques. Hence they cannot be considered reliable in a scientific sense. There is no way of assessing the range of body size they will accommodate. It can be demonstrated, moreover, that there is no such thing as an "average" person, either male or female (Daniels, G.S. The "Average Man"?). The engineer should design to accommodate the range of size of the using population.

14. Society of Automotive Engineers. Research Topics and Suggestions: Riding-Comfort Factors. The Journal of the Society of Automotive Engineers, Volume 14, No. 3, 1924, pp. 335-341.

This is a résumé of the topics and discussions in a symposium on riding-comfort factors. This symposium, primarily for engineers, was held 22 January 1924. Factors involved in riding comfort were discussed under the breakdown of the passenger, the vehicle and the road. An outline of the factors discussed is presented along with portions of the discussion. A nineteen-item bibliography is included.

15. Thruelsen, Richard. Have a Seat, Please. Saturday Evening Post, Volume 219, 28 September 1946, p. 6.

This article discusses the size and durability problems of theater seat design. "The prime goal is to design a chair which not only fits the callipygian curves but pampers the popliteal tendons -- in other words, feels like a downy yet dependable cloud. Cast-iron standards, hidden hinges, African grass or palm fiber and arched springs are utilized in these seats.

"To meet the crisis of the patron who tries to fit a nineteen-inch spread into a seventeen-inch seat, the new manufacturing trend is to widths between nineteen and twenty-one inches, with a twenty-four-incher now being planned."

Other problems include spacing of rows and within rows, and durability. Two devices, one which sits down in the test chair with 270 pounds of dead weight 100 times a minute and another which gives the seat and the standard a wallop like that of a forty-pound weight dropping twelve inches, are utilized in testing by one manufacturer, the American Seating Company.

The article contains two illustrations and no bibliographic references.

16. Yoder, Robert M. Some of Your Best Friends Are Dummies. The Saturday Evening Post, 10 July 1954.

This article describes the use of anthropomorphic (or anthropometric) dummies in accident research. The dummies are designed to represent as accurately as possible the physical characteristics of the human body in order to obtain reliable estimates of the effects on the human body of various types and intensities of accidents or accident-like situations. The effectiveness of various accident-minimizing devices --such as seat belts and ejection seats--can also be evaluated by means of such studies.

The article is four pages long. There are no tables, figures, or data. Five photographs of the dummies "in action" are included. Many of the leading authorities in accident research, as well as installations where such work is being conducted, are named.

17. Army Service Forces. Height and Weight Data for Men Inducted into the Army and for Rejected Men. Report No. 1-BM, Office of the Surgeon General, Medical Statistics Division, (World War II data, no report date given).

"A sample of 101,142 records for selectees examined at induction stations during January and May 1943 indicates that for the men inducted into the Army:

Average height (without shoes) was 68.11 inches
Average weight (without clothes) was 150.75 pounds

"The average height and weight of the men rejected were respectively .29 inch less and .66 pound less than for the men inducted into the Army.

"The average height and weight of white and colored men inducted into the Army were as follows:

	Average Height	Average Weight
White inductees	68.14 inches	150.78 pounds
Colored inductees	67.89 inches	150.14 pounds

"The average height and weight of white and colored men who were rejected were slightly under the corresponding measurements for men inducted into the Army.

"Among the men inducted into the Army, approximately 83 percent were from 5'5" to 5'11" tall. The standard deviation of the heights (with respect to the mean of 68.11 inches) was 2.59 inches.

"Approximately 80 percent of the men inducted fell into the weight range from 120 lbs. to 170 lbs. The standard deviation of the weight (with respect to the mean of 150.76 pounds) was 22.18 pounds.

"The average height of the inductees examined in 1943 was .62 inch greater than the average height of Army recruits in 1917.

"The draft recruits examined in 1917 had an average weight of 141.54 pounds or about 9 pounds less than the average for men inducted in 1943."

The composition of the sample is shown below.

	White		Colored		Total	
Inducted into Army	60,695	68.9%	7,300	55.9%	67,995	67.2%
Rejected	27,392	31.1%	5,755	44.1%	33,147	32.8%
Total sample	88,087	100.0%	13,055	100.0%	101,142	100.0%

"It should be kept in mind that the registrants presenting themselves for examination at the induction stations were a selected sample of the population. Not only were the men in deferred occupations and the men with dependents automatically eliminated but in addition there was a physical screening of the registrants at the local boards. Only men with manifestly disqualifying defects were rejected at the local board level. Specific causes for rejection, relative to height and weight, were "dwarfism", "gigantism or acromegaly if markedly disfiguring or if associated with other symptoms or severe pituitary disfunction", and "excessive overweight which is greatly out of proportion to height if sufficient to interfere with normal physical activity or with proper training". In addition, however, men with serious organic diseases (such as advanced tuberculosis, cancer, etc.) which might have greatly affected their weight, would also have been rejected by the local boards."

"The heights were recorded without shoes and the weights without clothing.

"The tabulations of height and weight presented in this study should be regarded as approximations of true height and weight of selectees examined at induction stations. For practical purposes, it was not essential that observations of height and weight be recorded with a high degree of exactness. Height was most often reported in an integral number of inches, though sometimes it was given to the nearest half inch or quarter inch. Whole numbers of inches were used in transferring height data from individual reports of examinations (DSS Form 221) to punch cards, from which the tabulations presented in this study were obtained. Thus, the tables showing the distributions of selectees by height are drawn up on the basis of the whole number of inches reported, disregarding any fractional parts of an inch. A tabulation of a small sample of cases indicated that the heights reported averaged approximately two-tenths of an inch in excess of the whole number of inches. Accordingly the mean for the group of cases reported as 70 inches and 70 plus some fractional part of an inch can be taken as 70.2 inches."

The body of the report includes four charts and the appendix includes 11 tables. The 14 page report has no bibliographic references. The four charts are included in the annotation to summarize the data; these are: I. Percent Distribution of Heights; II. Percent Distribution of Heights and of Weights (Comparing 1943 and 1917 groups); III. Percent Distribution of Weights; and IV. Average Weight by Height (1943 and 1917 curves).

CHART 17 - 1

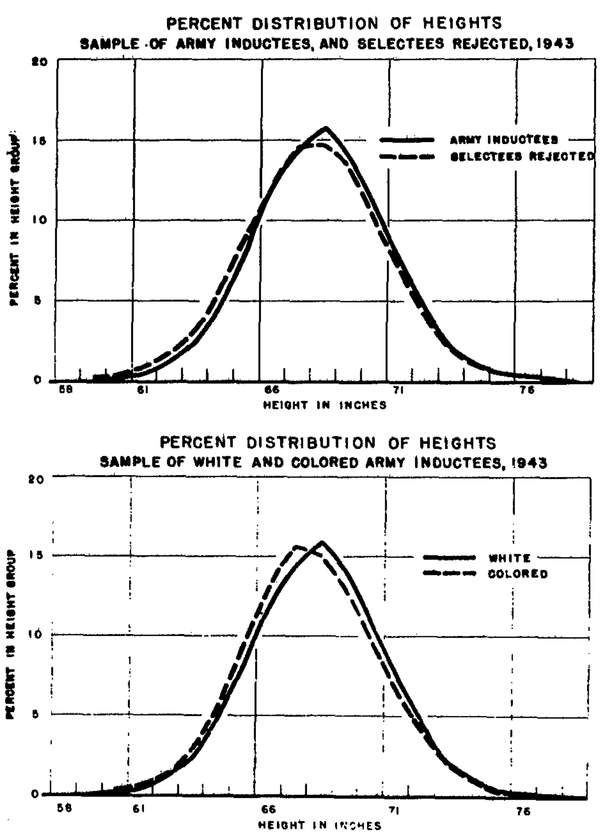


CHART 17 - 2

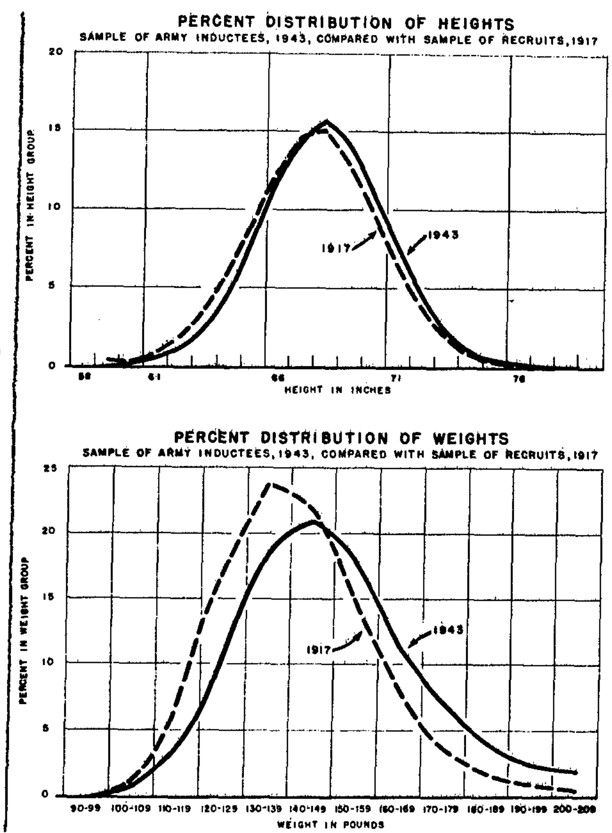
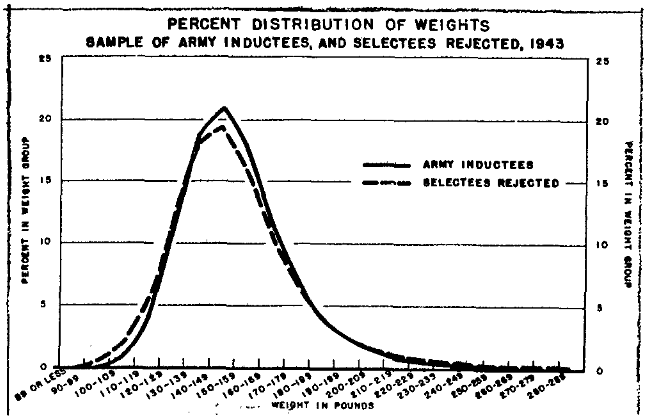


CHART 17 - 3



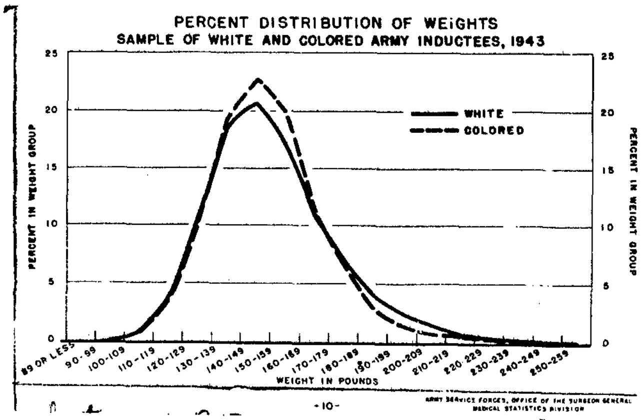


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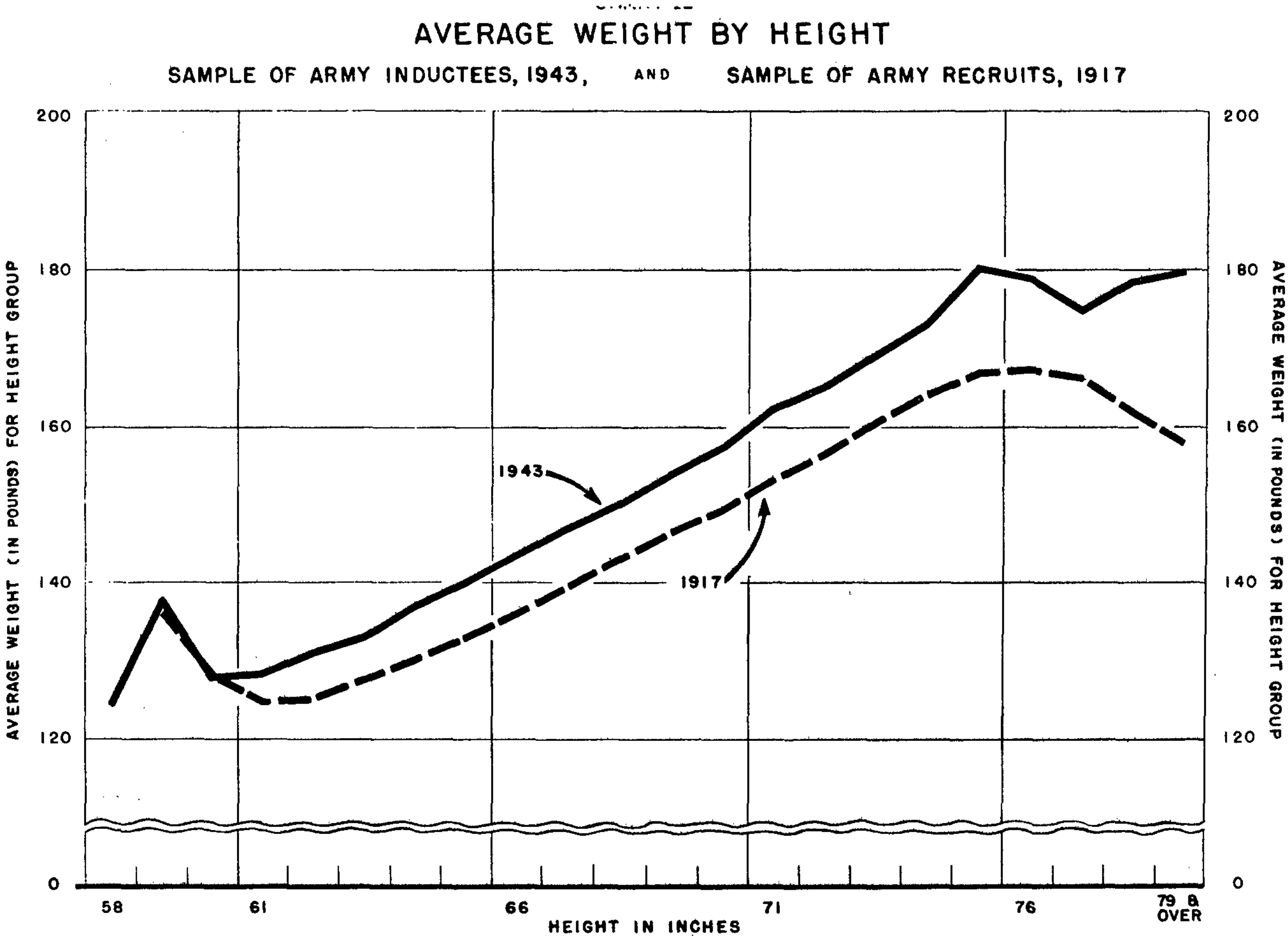
CHART 17 - 4



18. Ashe, William F., Paul Bodenman, and Lester B. Roberts. Anthropometric Measurements. Project No. 9, File No. 741-3, Armored Force Medical Research Laboratory, Fort Knox, Kentucky, 1 February 1943.

Purpose: To determine the size of various parts of the human body to facilitate the proper design of equipment, particularly Armored Vehicles.

Background and methodology: "The Aero-Medical Research Laboratory at Dayton, Ohio, has made available to this Laboratory a considerable amount of data on the size of Air Force Personnel. This data has been used in the design of Air Force equipment.

"Much of the data supplied by the Air Force is directly applicable to Armored Force personnel if it can be demonstrated that the two populations are similar. Certain standard basic measurements such as height, weight, sitting height, shoulder and hip width, and arm reach were made on a group of 250 Armored Force School soldiers and compared with the much larger Air Corps group. The two groups were found to be essentially alike.

"The problems of Armored Force vehicular design required that certain measurements be made which were not made on Air Corps personnel. The instruments used for these measurements were in part borrowed from the group at Harvard which measured the Air Corps personnel, and the rest were fabricated with equal accuracy.

"The additional necessary measurements were made on over 900 Armored Force School soldiers. The data here presented includes all relevant information from both groups of statistics.

Conclusion: "This material is a sound basis upon which to design Armored Force equipment, particularly such Armored Force vehicles as tanks, in which space requirements are of the greatest importance."

The authors describe techniques for taking 36 body measurements. The report is 37 pages long. The data are presented in the form of 37 percentile distributions. There is no bibliography.

The following table provides selected material from the report.

TABLE 18 - 1

Anthropometric Data

Note: Where N = approximately 2900, the data are based on Air Force personnel. Where N = 900 or less, the data are based on Armored Force School soldiers. (Measurements are in inches unless specified to the contrary).

Measurement	Number of Subjects	Range	Percentiles 5th	50th	95th
1. Stature	2961	61.4 - 78.0	65.4	69.2	73.1
2. Weight (lb)	2960	110 - 210	128.54	153.12	184.04
3. Sitting Height	2959	32.7 - 40.6	34.5	36.4	38.5
4. Shoulder Height	912	20.2 - 28.7	22.7	24.5	26.5
5. Eye Height	915	3.4 - 5.7	3.9	4.4	5.1
6. Anterior Arm Reach	2959	29.5 - 40.6	32.7	35.2	37.8
7. Shoulder-Elbow Height	2955	10.6 - 16.9	13.6	14.7	15.8
8. Elbow to Fingertips	101	16 3/4 - 21 7/8	17 1/2	18 3/4	20 1/2
9. Elbow to Center of Fist	101	12 3/8 - 16 3/8	13	14 1/8	15 1/2
10. Hand Length	2952	6.4 - 8.8	7.1	7.6	8.2

Measurement	Number of Subjects	Range	Percentiles 5th	50th	95th
11. Hand Breadth	2955	2.9 - 4.1	3.1	3.4	3.7
12. Bi-Deltoid	2955	15.4 - 20.5	16.7	18.0	19.3
13. Biacromial	2956	12.6 - 18.1	14.4	15.7	16.9
14. Span Total	2959	62.2 - 80.7	67.2	71.5	76.1
15. Span Akimbo	2956	31.9 - 42.5	34.7	37.1	39.7
16. Chest Thickness	914	7.9 - 12.3	8.6	9.6	10.8
17. Chest Width	918	12.5 - 16.8	13.3	14.3	15.5
18. Chest Breadth	2957	8.7 - 13.4	10.3	11.3	12.4
19. Chest Depth	2959	6.3 - 11.0	7.2	8.2	9.3
20. Abdominal Depth	2958	6.3 - 10.6	7.21	8.18	9.33
21. Buttock Knee	2954	19.3 - 27.6	22.0	23.6	25.6
22. Patella Height-from Floor	2959	18.1 - 25.6	20.4	22.0	23.6
23. Foot Length	2959	8.8 - 12.2	9.8	10.5	11.3
24. Foot Breadth	2959	3.3 - 4.6	3.6	3.9	4.2
25. Shoe Length	917	10.1 - 13.5	11.0	11.7	12.6
26. Shoe Width	912	3.7 - 4.6	3.9	4.2	4.4
27. Bi-Trochanteric	2954	11.8 - 18.5	13.1	14.2	15.5
28. Bi-Iliac	2956	9.1 - 13.4	10.4	11.4	12.4
29. Bi-Epicondylar-Elbows	2955	12.6 - 21.3	15.1	16.7	18.4
30. Head Circumference	2955	20.1 - 24.4		22.4	23.4
31. Chest Circumference-Rest	2954	30.7 - 43.3	33.1	35.7	39.0
32. Calf Circumference-Left	2955	11.0 - 17.7	12.8	14.1	15.6
33. Head Height	2956	4.3 - 6.0	4.8	5.2	5.6
34. Sitting Height Minus Head Height	2955	27.6 - 35.4	29.6	31.4	33.3
35. Trunk Height	2957	19.7 - 27.2	22.2	23.8	25.3
36. Bi-Epicondylar Femoral-Knees	2955	6.3 - 11.4	7.1	7.7	8.4
37. Squatting Diagonal	2955	28.0 - 40.2	31.1	33.4	35.9

19. Baxter, J.H. Statistics - Medical and Anthropological of the Provost-Marshal-General's Bureau derived from Records of the Examination for Military Service in the Armies of the United States during the Late War of Rebellion of over a Million Recruits, Drafted Men, Substitutes and Enrolled Men. Washington, D.C.: Government Printing Office, 1875, 2 Volumes, 1335 pages.

This report is primarily oriented toward the medical examination with reports of disease and injuries; however, figures for height, weight and girth of chest are included. Introductory sections discuss similar anthropometric data for certain European national groups. The following tables summarize this anthropometric material.

Volume One includes the plan and scope of the work, instructions to recruiting-surgeons, an outline of the history of anthropometry, a review of the tables (which appear in Volume Two) and their results, 60 charts and maps, and the reports of surgeons of boards of enrollment. Included are charts (bar graphs) of Girth of Chest at Expiration - in its relation to Nativity (European nationality) and Age, Height - in its relation to Nativity and Age, and a general index for both volumes. The instructions to recruiting-surgeons include anthropometric selection data for the Roman soldier, the French, British, Belgian, Swiss, North-German and Austrian soldiers. A table is included which "exhibits the changes that have been made in the stature and age required of recruits for the Army of the United States from 1790 until the present day (1874).

Volume Two consists of 767 pages of tables which present stature, complexion, age and disease in relation to each other and to such other factors as native and foreign birth and geographical (U.S.) origin. The N (number of subjects) is given for each table. For example, Table I is entitled: "The Relation of Height, Girth of Chest, and Expansion of Chest by States and Congressional Districts - American-born White Men - Number Examined 315,620."

Bibliographic references are given for data presented in the section on history of anthropometry.

TABLE 19 - 1

Record of Observations of Mean Physical Qualities of Certain Races of Men, From Various Authorities.

Nativity or race.	Mean age.	Mean height.		Mean circumference of chest.		
	Years.	*Inches.*	*Metres.*	*Inches.*	*Millimet.*	
UNITED STATES:						
White natives	24.01	67.36	1.711	....	....	1
	23.94	67.05	1.703	34.99	•888	2
	....	68.20	1.732	....	....	3
	....	67.00	1.702	33.97	862	4
	21.72	67.81	1.722	36.14	917	5
	25.62	67.34	1.710	34.43	874	6
	....	67.22	1.707	35.69	906	7
	24.09	67.90	....	....	....	8
	26.39	67.30	1.709	32.49	825	9
	....	67.67	1.719	33.42	848	10
	26.96	67.35	1.711	33.63	854	11
	....	67.41	1.712	33.17	842	12
	....	67.93	1.725	33.68	855	13
Colored men	....	66.78	1.696	35.21	894	14
	....	66.53	1.690	33.69	855	15
	23.30	66.39	1.686	32.84	834	16
	[illegible]8.00	61.22	1.555	33.29	845	17
Indians	....	67.97	1.726	37.89	962	18
	....	67.93	1.725	34.07	865	19
	32.00	73.82	1.875	36.25	920	20
	All adults	66.95	1.701	....	....	21
BRITISH AMERICA:						
White natives	25.53	66.91	1.700	34.38	873	22
	24.28	67.14	....	....	....	23
	....	67.01	1.702	33.38	847	24
	24.94	67.06	1.703	32.67	829	25
	25.24	67.13	1.705	33.55	852	26
ENGLISHMEN	19.95	66.80	1.697	....	....	27
	....	67.30	1.709	35.71	906	28
	....	66.40	1.687	....	....	29
	....	66.49	1.689	....	....	30
	....	66.60	1.692	....	....	31
	24.31	....	....	....	....	32
	26.28	66.74	1.695	....	....	33
	24.00	65.94	1.675	....	....	34
	....	66.58	1.691	....	....	35
	27.36	66.35	1.685	32.75	831	36
	27.89	66.58	1.691	33.45	849	37
SCOTCHMEN	Adults	67.90	1.725	39.86	1,012	38
	23 to 45	67.72	1.720	....	....	39
	25.00	68.30	1.735	....	....	40
	28.91	66.94	1.700	34.67	880	41
	27.24	67.26	1.708	....	....	42
	18 to 45	67.07	1.704	33.84	859	43
IRISHMEN	25.00	69.20	1.758	....	....	44
	23 to 45	....	....	....	....	45

	Mean weight.		Authority.
	Pounds.	*Kilos.*	
1	148.29	67.26	COOLIDGE.[1] 1,537 recruits; 1839 to 1855.
2	147.50	66.91	ELLIOTT.[2] 1,700 soldiers of the Army of the Potomac; no recruits included.
3	....	....	ELLIOTT.[3] 25,878 volunteer recruits.
4	....	....	TRIPLER.[4] 150 recruits; 1853 to 1855.
5	139.49	63.27	ALLEN.[5] Students at Amherst College from 1861 to 1869.
6	144.83	65.69	GOULD.[6] 8,349 soldiers; all volunteers.
7	142.80	64.77	GOULD.[7] 12,751 s ldiers; all volunteers.
8	....	....	GOULD.[8] 833,260 soldiers; descriptions obtained from State archives.
9	136.05	61.71	THE PRESENT WORK. 6,359 accepted men.
10	....	....	THE PRESENT WORK. 315,620 men, both accepted and rejected.
11	....	....	THE PRESENT WORK. 196,980 accepted men.
12	....	....	THE PRESENT WORK. 29,930 men from New England, both accepted and rejected.
13	....	....	THE PRESENT WORK. 77,665 men from Ohio and Indiana, both accepted and rejected.
14	147.47	•66.89	GOULD.[9] 1,769 soldiers; all volunteers.
15	....	....	THE PRESENT WORK. 25,828 men, both accepted and rejected.
16	141.67	64.26	THE PRESENT WORK. 377 accepted men.
17	....	....	QUETELET.[10] Number of observations not given.
18	161.84	73.41	GOULD.[11] 456 Iroquois Indians.
19	....	....	THE PRESENT WORK. 121 Indians accepted as volunteers.
20	....	....	QUETELET.[12] An O-jib-be-wa chief of fine proportions.
21	....	....	MAJOR-GENERAL LEFROY.[13] 33 Chippewas.
22	....	....	GOULD.[14] 588 volunteers in United States Army.
23	....	....	GOULD.[15] 38,018 volunteers; descriptions obtained from State archives.
24	....	....	THE PRESENT WORK. 21,645 men, both accepted and rejected.
25	138.69	62.91	THE PRESENT WORK. 589 accepted men.
26	....	....	THE PRESENT WORK. 14,954 accepted men.
27	131.00	59.42	ENGLISH ARMY MEDICAL REPORTS[16] for 1869 and 1870; mean of both reports. These are recruits only.
28	143.00	64.86	A. S. THOMSON.[17] 628 soldiers of Fifty-eighth Regiment.
29	....	....	BOYD.[18] Civilians; the mean has been calculated of his entire range.
30	....	....	BOUDIN.[19] Soldiers.
31	138.06	62.62	BEDDOE.[20] 9,187 men: 7,119 civilians and 2,068 soldiers; includes, also, a few men from Wales.
32	148.41	67.32	COOLIDGE.[21] 3,439 men in Uni ed States Army.
33	....	....	GOULD.[22] 30,037 volunteers. GOULD.[23] 306 volunteers.
34	138.46	62.81	DANSON.[24] 1,500 men from civil life.
35	....	....	THE PRESENT WORK. 16,196 men, both accepted and rejected.
36	135.64	61.53	THE PRESENT WORK. 454 accepted men.
37	....	....	THE PRESENT WORK. 10,103 accepted men.
38	....	....	EDIN. MED. AND SURG. JOUR.[25] 5,731 men. See *ante*, p. lxix, for remarks on dimensions of the chest.
39	148.69	67.45	BEDDOE.[26] 1,982 men taken without selection: 1,423 civilians and 559 soldiers.
40	144.03	65.33	FORBES.[27] 829 students of University of Edinburgh; 1/16 for weight of clothes, and 1 inch for thickness of soles of shoes, have been deducted.
41	....	....	GOULD.[28] 81 Scotchmen in United States Volunteer Army.
42	....	....	GOULD.[29] 7,313 men. Descriptions obtained from State archives.
43	....	....	THE PRESENT WORK. 3,476 men, both accepted and rejected.
44	155.00	70.31	FORBES.[30] Students and civilians.
45	137.98	62.59	BEDDOE.[31] 1,616 men, taken without selection; nearly all soldiers.

TABLE 19 - 1 (Continued)

Nativity or race.	Mean age.	Mean height.		Mean circumference of chest.		
	Years.	Inches.	Metres.	Inches.	Millimet.	
IRISHMEN—Continued	....	66.92	1.700	....	....	46
	29.24	65.66	1.668	35.15	892	47
	26.51	66.95	1.701	....	....	48
	....	66.74	1.695	33.77	857	49
	26.80	66.59	1.691	33.12	841	50
	27.22	66.75	1.695	33.82	858	51
FRENCHMEN	20	63.58	1.615	....	....	52
	20	65.16	1.655	....	....	53
	20	65.12	1.654	....	....	54
	Adults	65.75	1.670	....	....	55
	Adults	66.10	1.679	....	....	56
	Adults	64.96	1.650	....	....	57
	30.50	64.84	1.647	34.61	878	58
	30	66.10	1.679	35.43	899	59
	....	66.50	1.689	....	....	60
	....	66.28	1.684	33.78	857	61
	27.74	65.66	1.668	34.30	871	62
BELGIANS	....	64.68	1.643	....	....	63
GERMANS	....	65.15	1.655	....	....	64
	29.76	66.17	1.681	34.72	881	65
	27.34	66.66	1.693	....	....	66
	....	68.11	1.730	....	....	67
	....	66.54	1.690	33.88	860	68
	30.10	65.98	1.676	33.05	839	69
	31.03	66.51	1.689	33.97	862	70
Austrians	....	68.90	1.750	....	....	71
Saxons	....	67.40	1.712	....	....	72
Bavarians	....	64.72	1.644	....	....	73
ITALIANS	....	67.14	1.705	....	....	74
	....	66.00	1.676	33.40	848	75
CHINESE	Adults	65.76	1.670	33.33	846	76

1 *Statistical report of sickness and mortality in U. S. Army from* 1839 *to* 1855, 4to, Washington, 1856, p. 632.
2 *Military statistics of United States of America*, 4to, Berlin, 1863, pp. 12, 16, 19, 21.
3 *Ibid.*, p. 15.
4 *Manual of medical officer*, 16mo, Washington, 1866, p. 21.
5 *Physical culture in Amherst College*, 8vo, Lowell, 1869; appendix.
6 *Investigations in the military and anthropological statistics of American soldiers*, 8vo, New York, 1869, pp. 276–279, 402.
7 *Ibid.*, pp. 446–447.
8 *Ibid*, p. 104.
9 *Ibid.*, p. 452.
10 *Anthropométrie*, 8vo, Paris, 1871, p. 333.
11 *Op cit*, p. 453.
12 *Op. cit.*, p. 316.
13 *Jour. Ethnol. Soc. London*, April, 1870.
14 *Op. cit.*, pp. 276, 278.
15 *Op. cit.*, p. 104.
16 *Army med. reports* for 1869, p. 51; for 1870, p. 44.
17 *Observations on stature of N. Zealand race of men*, Geogr. Soc. Jour., vol. xxvii, pp. 87–92. London, 1853.
18 *Tables of the weight of the human body*, Philos. Trans., 1861, pp. 241–262.
19 *Études ethnologiques sur la taille et le poids de l'homme*, Recueil de mém. de méd., etc., 3 sér., t. ix, p. 192.
20 *On the stature and bulk of man in the British Isles*, 8vo. London, 1870.
21 *Op. cit*, p. 632.
22 *Op. cit.*, p. 105.
23 *Op cit.*, pp. 279, 280.
24 *Statistical observations relative to growth of human body*, Jour. Statist. Soc., vol. xxv, pp. 20–26. London, 1862.
25 Vol. xiii, p. 263.
26 *Op. cit.*; calculated from the tables.
27 *On the results of experiments on weight, height, and strength of 800 individuals*, Rep. Brit. Assoc., 1836, part II, p. 38.

TABLE 19 - 1 (Continued)

	Mean weight.		Authority.
	Pounds.	*Kilos.*	
46	....	....	TRIPLER.[32] Recruits, 1853 to 1855.
47	....	....	GOULD.[33] 827 soldiers.
48	....	....	GOULD.[34] 83,128 volunteers.
49	....	....	THE PRESENT WORK. 50,537 men, both accepted and rejected.
50	136.46	61.90	THE PRESENT WORK. 1,417 accepted men.
51	....	....	THE PRESENT WORK. 30,412 accepted men.
52	....	....	HARGENVILLIERS.[35] Conscripts, prior to 1816.
53	....	....	CHENU.[36] 3,300,000 conscripts, from 1830 to 1865.
54	....	....	BOUDIN.[37] 848,506 conscripts, in 1861 and 1862.
55	....	....	BOUDIN.[38] Entire army.
56	142.20	64.50	BOUDIN.[39] *Chasseurs à cheval.*
57	....	....	BROCA.[40] Estimate of adult male population.
58	143.20	64.96	BERNARD.[41] 400 *chasseurs à pied* of the guard.
59	141.10	64.00	ALLAIRE.[42] 730 *chasseurs à cheval* of the guard.
60	....	....	TRIPLER.[43] Recruits in United States Army from 1853 to 1855.
61	....	....	THE PRESENT WORK. 3,243 men, both accepted and rejected.
62	....	....	GOULD.[44] 100 volunteers in United States Army.
63	....	....	QUETELET.[45]. 10,400 soldiers.
64	....	....	TRIPLER.[46] Recruits in United States Army, from 1853 to 1855.
65	....	....	GOULD.[47] 562 volunteers in United States Army.
66	....	....	GOULD.[48] 89,021 volunteers; descriptions obtained from State archives.
67	....	....	ZEISING.[49] Citizens.
68	....	....	THE PRESENT WORK. 54,944 men, both accepted and rejected.
69	136.48	61.91	THE PRESENT WORK. 1,343 accepted men.
70	....	....	THE PRESENT WORK. 30,943 accepted men.
71	....	....	LIHARZIK.[50] 300 picked men.
72	....	....	CARUS.[51] Citizens.
73	145.43	65.97	MEYER.[52] 12,740 men drafted for the army.
74	....	....	BODIO.[53] 100,000 conscripts for army.
75	....	....	THE PRESENT WORK. 339 men, both accepted and rejected.
76	129.34	58.67	BRIGHAM.[54] 150 men returning to China.

[28] *Op. cit.*, pp. 279, 280.
[29] *Op. cit.*, p. 105.
[30] *Op. cit.*, p. 40.
[31] *Op. cit*; calculated from tables.
[32] *Op. cit.*, p. 11.
[33] *Op. cit.*, pp. 279, 280.
[34] *Op. cit.*, p. 105.
[35] *Recherches et considérations sur la formation et le recrutement de l'armée en France*, 8vo, Paris, 1817, pp. 52, 65.
[36] *Recrutement de l'armée et population de la France*, 4to, Paris, 1867.
[37] *Recueil de mém. de méd., chir., etc.*. 3 sér., t. ix, p. 184.
[38] *Op. cit.*
[39] *Op. cit.*
[40] *Recherches sur l'ethnologie de la France*, 8vo, Paris, 1860.
[41] *Études sur la taille et le poids du soldat français*. Recueil de mém. de méd., chir. et pharm. militaires, 3 sér., t. xx, p. 371, Paris, 1868.
[42] *Études sur la taille et le poids de l'homme dans le regiment des chasseurs à cheval de la garde*, Recueil de mém. de méd., etc., 3 sér., t. x, p. 161, Paris, 1863.
[43] *Op. cit.*, p. 11.
[44] *Op. cit.*, pp. 279, 280.
[45] *Sur l'homme et le développement de ses facultés*, 2 t., 8vo, Paris, 1835; t. ii, pp. 11, 13, 23.
[46] *Op. cit.*, p. 11.
[47] *Op. cit.*, pp. 279–280.
[48] *Op. cit.*, p. 105.
[49] *Die metamorphosen in den verhältnissen der menschlichen gestalt* folio, Bonn, 1859, p. 123.
[50] *Das gesetz des wachsthumes und der bau des menschen*, folio, Vienna, 1862.
[51] *Die proportionslehre der menschlichen gestalt*, folio, Leipsic, 1854.
[52] *Aerztliches intelligenz-blatt von Bayern*, 1863.
[53] *Bull. de l'Acad. roy. de Belgique*. 2 sér., t. xxvii, No. 3, 1869.
[54] *Proc. Boston Soc. Nat. Hist.*, vol. xi, p. 98, 1866–'68.

20. Daniels, G.S., H.C. Meyers and E. Churchill. Anthropometry of Male Basic Trainees. WADC Technical Report 53-49, USAF, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, July 1953, (ASTIA No. AD-21105).

Body size data for 60 measurements of over 3,000 Air Force male basic trainees are presented for use by aircraft and equipment designers.

The statistics reported for each measurement are: the mean, standard deviation, coefficient of variation, standard errors of these statistics, range, and selected percentiles from the first to the ninety-ninth. In general, the statistics are reported in both the metric and English values.

A complete description of the anthropometric techniques used is presented.

The measuring for this study was limited to basic trainees primarily because the greatest issue of clothing items to personnel has taken place during basic training.

Measuring of subjects was performed between 10 July and 1 August 1952. The information has been recorded on IBM punch cards which are filed in the Anthropology Section, Aero Medical Laboratory, Wright Air Development Center.

Age ranged from 17 to 36 years, with 87.84% in the 17-20 year range. The mean age for the group was 18.94 $\pm$ .03 years.

A bibliography and index are included.

Table 20-1 presents essential dimensional data from the report.

21. Daniels, G.S., H.C. Meyers and Sheryl H. Worrall. Anthropometry of WAF Basic Trainees. WADC Technical Report 53-12, USAF, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, July 1953, (ASTIA No. AD-20717).

Body size data for 63 measurements of 852 Women's Air Force basic trainees are presented for use by the designers of Air Force Equipment. In the original report the statistics, for most measurements, are reported in both metric and English values.

A complete description of the anthropometric techniques used is presented. For each measurement, a title, written description, and a graphic description are given. The data include the range, number of subjects, mean, standard deviation, coefficient of variation and selected percentile values from the first to the ninety-ninth.

This study of Air Force women has been restricted to basic trainees because the greatest issue of clothing items to WAF personnel has taken place during basic training and because only at the basic training center were sufficient concentrations of subjects available.

Measuring of subjects was performed between 17 July and 1 August 1952. The information has been recorded on IBM punch cards which are filed in the Anthropology Section, Aero Medical Laboratory, Wright Air Development Center.

Age ranged from 18 to 34 years, with 76% in the 18-20 year range. The mean age for the group was 19.79 $\pm$ .09 years.

A bibliography and index are included.

Table 21 - 1 presents essential dimensional data from the report.

TABLE 20 - 1

Male Air Force Basic Trainee Anthropometric Data

Measurement	N	Range	Mean	S.D.	Percentile 1st	5th	50th	95th	99th
Weight (lbs.)	3332	100. -295.	147.44±.36	20.97±.26	108.6	118.4	145.4	186.3	208.4
Stature	3331	61.0 - 76.4	68.54±.05	2.61±.03	62.5	64.2	68.6	72.7	74.7
Cervicale Height	3330	51.6 - 66.9	58.73±.04	2.43±.03	53.1	54.7	58.7	62.7	64.7
Acromial Height	3326	48.0 - 63.8	55.9 ±.04	2.41±.03	50.3	52.0	55.9	59.9	61.8
Axilla Height	2017	44.5 - 59.8	52.59±.05	2.24±.04	47.2	49.0	52.6	56.5	57.8
Waist Height	3319	32.3 - 48.8	41.62±.04	2.01±.02	37.1	38.5	41.6	45.0	46.6
Gluteal Furrow Height	3330	24.8 - 38.98	31.70±.03	1.72±.02	27.7	28.9	31.7	34.6	35.9
Crotch Height (Inseam)	2024	25.6 - 39.4	33.20±.04	1.74±.03	29.2	30.4	33.2	36.0	37.5
Patella Height	2759	15.7 - 24.4	20.72±.02	1.15±.02	18.1	18.9	20.7	22.7	23.5
Calf Height	3321	9.8 - 19.7	13.84±.02	1.07±.01	11.5	12.2	13.8	15.6	16.5
Ankle Height	3329	1.89- 3.27	2.59±.01	.19±.01	2.14	2.27	2.59	2.89	3.04
Chest Breadth	3326	7.9 - 15.7	11.46±.02	.91±.01	9.69	10.20	11.38	12.99	14.33
Hip Breadth	3328	9.1 - 19.3	13.35±.02	.94±.01	11.5	12.1	13.3	15.0	16.3
Neck Circumference	3322	11.4 - 17.7	14.27±.01	.76±.01	12.6	13.1	14.3	15.6	16.3
Shoulder Circumference	1460	35.4 - 50.8	42.59±.06	2.19±.04	37.9	39.2	42.5	46.3	48.5
Chest Circumference (Relaxed)	3330	29.1 - 47.6	35.58±.04	2.39±.03	30.9	32.1	35.4	39.8	42.7
Chest Circumference (Expanded)	3323	30.7 - 48.8	36.89±.04	2.35±.03	32.3	33.2	36.6	41.0	43.5
Waist Circumference	3325	23.2 - 46.9	30.32±.05	2.73±.03	25.7	26.9	29.9	35.5	39.8
Buttocks Circumference	3324	29.1 - 48.0	36.33±.04	2.41±.03	31.9	33.0	36.0	40.7	43.8
Thigh Circumference	3321	14.6 - 32.3	21.41±.04	2.04±.03	17.8	18.7	21.1	25.2	27.4
Lower Thigh Circumference	3328	10.2 - 20.9	14.89±.02	1.24±.01	12.6	13.1	14.8	17.1	18.4
Calf Circumference	3327	7.9 - 18.1	13.88±.02	1.05±.01	11.8	12.3	13.8	15.7	16.6
Ankle Circumference	3326	7.1 - 13.0	8.81±.01	.59±.01	7.64	7.96	8.78	9.79	10.46
Arm Scye	3325	7.9 - 23.6	16.80±.03	1.45±.02	13.3	14.8	16.8	18.9	20.3
Axillary Arm Circumference	3329	7.9 - 20.1	12.44±.02	1.28±.02	9.8	10.7	12.3	14.5	16.4
Biceps Circumference (Flexed)	3326	7.9 - 16.9	12.16±.02	1.10±.01	9.9	10.5	12.1	14.0	15.1
Elbow Circumference (Flexed)	1459	7.9 - 15.7	11.77±.02	.86±.02	9.96	10.59	11.69	13.11	14.80
Lower Arm Circumference(Flexed)	1298	6.3 - 15.0	10.66±.02	.86±.02	8.64	9.45	10.63	12.01	12.72
Wrist Circumference	3326	5.5 - 9.1	6.87±.01	.40±.01	6.07	6.28	6.89	7.58	7.85
Sleeve Inseam	3313	10.6 - 23.6	18.83±.02	1.24±.02	16.1	16.9	18.8	20.9	21.9

Note: Dimensions are in inches, unless otherwise noted.
S.D. is standard deviation.

TABLE 20 - 1 (Continued)

Measurement	N	Range	Mean	S.D.	Percentile 1st	5th	50th	95th	99th
Sleeve Length	1999	26.8 - 38.6	31.72±.03	1.48±.02	28.4	29.4	31.7	34.3	35.2
Shoulder Length	3304	4.3 - 9.4	6.99±.01	.68±.01	5.47	5.92	6.97	8.09	8.57
Biacromial Arc	1421	14.2 - 24.4	19.83±.04	1.52±.03	16.2	17.4	19.8	22.2	23.3
Waist Back	1995	14.2 - 23.2	18.42±.03	1.22±.02	15.7	16.5	18.4	20.5	21.9
Waist Front to Cervicale	2758	15.7 - 28.3	22.02±.02	1.25±.02	18.5	20.2	22.0	24.0	25.1
Gluteal Arc	2012	7.9 - 14.2	10.34±.02	.81±.01	8.62	9.09	10.31	11.69	12.20
Crotch Length	1458	16.1 - 35.4	26.51±.06	2.22±.04	21.2	23.0	26.4	30.4	32.8
Vertical Trunk Circumference	1457	55.1 - 74.4	63.17±.08	3.05±.06	56.9	58.5	63.0	68.4	71.2
Interscye (Sitting)	3325	13.4 - 24.8	18.93±.03	1.46±.02	15.7	16.6	18.9	21.4	22.6
Interscye Maximum	3331	15.7 - 27.2	21.37±.03	1.60±.02	17.8	18.9	21.3	24.1	25.5
Hip Circumference (Sitting)	3323	32.7 - 53.9	39.57±.05	2.90±.04	34.5	35.7	39.3	45.0	48.7
Knee Circumference (Sitting)	3329	9.8 - 20.9	15.11±.02	1.05±.01	12.8	13.7	15.0	16.9	18.0
Foot Length	3331	8.7 - 12.3	10.34±.01	.50±.01	9.2	9.5	10.3	11.2	11.5
Instep Length	2766	5.6 - 8.9	6.96±.01	.40±.01	6.09	6.33	6.93	7.61	8.01
Foot Width	3327	3.2 - 5.1	4.01±.00	.25±.00	3.49	3.63	3.99	4.43	4.67
Heel Width	2020	2.0 - 3.3	2.65±.01	.17±.01	2.25	2.37	2.63	2.92	3.06
Ball of Foot Circumference	3322	8.3 - 13.4	9.86±.01	.53±.01	8.71	9.03	9.84	10.73	11.17
Hand Length	3328	6.42- 8.74	7.54±.01	.38±.01	6.67	6.94	7.54	8.18	8.51
Hand Breadth at Metacarpale	3317	2.76- 4.13	3.44±.01	.18±.01	3.04	3.15	3.45	3.73	3.88
Hand Breadth at Thumb	3316	3.2 - 5.0	4.12±.01	.25±.01	3.51	3.71	4.12	4.54	4.72
Thickness at Metacarpale III	2019	.79- 1.57	1.19±.01	.09±.01	.98	1.05	1.20	1.35	1.43
Palm Length	3321	3.23- 5.28	4.29±.01	.25±.01	3.69	3.92	4.29	4.71	4.91
Palm Circumference	3311	4.7 - 12.6	8.46±.01	.58±.01	7.28	7.67	8.42	9.23	10.02
Fist Circumference	3300	7.5 - 15.3	11.31±.01	.63±.01	9.84	10.39	11.30	12.28	12.72
Head Length	3317	6.50- 8.50	7.64±.01	.28±.01	6.95	7.17	7.63	8.09	8.25
Head Breadth	2019	5.2 - 7.2	5.95±.01	.23±.01	5.43	5.57	5.94	6.34	6.52
Head Circumference	3315	19.7 - 25.2	22.16±.01	.63±.01	20.7	21.2	22.1	23.2	23.6
Sagittal Arc	1460	11.0 - 17.3	14.90±.02	.80±.01	13.1	13.6	14.9	16.2	16.7
Coronal Arc	3322	11.4 - 15.7	13.87±.01	.58±.01	12.6	13.0	13.8	14.8	15.2
Posterior Arc	3351	7.1 - 15.0	10.87±.02	1.16±.01	8.94	9.29	10.63	13.03	13.98

Note: Dimensions are in inches, unless otherwise noted.
S.D. is standard deviation.

TABLE 21 - 1

Women's Air Force Basic Trainee Anthropometric Data

Measurement	N	Range	Mean	S.D.	Percentile 1st	5th	50th	95th	99th
Weight (lbs.)	851	84 -173	123.27±.50	14.54±.35	95.0	102.0	122.2	148.2	162.1
Stature	851	58.7 - 70.5	64.07±.08	2.34±.06	59.3	60.3	64.0	68.2	69.9
Cervicale Height	852	48.0 - 62.6	54.40±.08	2.33±.06	49.5	50.9	54.2	58.2	60.3
Acromial Height	849	46.1 - 58.7	51.76±.07	2.18±.05	46.9	48.2	51.9	55.4	57.3
Axilla Height	851	42.9 - 55.9	48.74±.08	2.22±.05	44.1	45.2	48.8	52.6	54.0
Waist Height	848	33.9 - 45.7	39.68±.06	1.85±.04	35.8	36.8	39.8	42.7	44.1
Gluteal Furrow Height	848	24.8 - 35.0	29.25±.05	1.58±.04	25.9	26.9	29.1	31.9	33.5
Crotch Height (Inseam)	851	26.0 - 35.8	30.31±.06	1.63±.04	27.3	28.0	30.2	33.1	34.3
Patella Height	847	12.6 - 24.4	19.20±.05	1.35±.03	15.2	16.9	19.3	21.3	22.5
Calf Height	851	10.2 -119.3	13.03±.04	1.07±.03	10.8	11.5	13.0	14.6	16.9
Ankle Height	845	1.8 - 2.8	2.37±.01	.15±.00	1.98	2.11	2.40	2.61	2.80
Chest Breadth	834	8.3 - 12.2	9.94±.02	.55±.01	8.9	9.1	9.9	10.9	11.3
Hip Breadth	850	9.8 - 18.5	13.80±.03	.95±.02	12.2	12.5	13.5	15.4	16.9
Neck Circumference	846	11.0 - 16.1	12.99±.02	.65±.02	11.6	11.9	12.8	14.1	14.8
Shoulder Circumference	851	33.1 - 42.9	37.80±.06	1.66±.04	34.2	35.2	37.8	40.6	41.9
Chest Circumference (Over)	852	26.8 - 38.2	32.35±.06	1.66±.04	28.6	29.8	32.4	35.2	36.5
Bust Circumference	851	26.8 - 40.9	33.70±.07	2.02±.05	29.1	30.5	33.6	37.0	38.6
Chest Circumference (Under)	850	24.0 - 36.2	29.57±.06	1.85±.04	25.5	26.6	29.3	32.8	34.6
Strap Length	851	19.7 - 31.9	24.72±.05	1.53±.04	21.3	22.3	24.6	27.3	28.7
Internipple Distance	850	5.9 - 11.0	7.63±.02	.62±.01	6.3	6.6	7.6	8.7	9.3
Waist Circumference	848	20.5 - 33.9	25.87±.06	1.63±.04	22.7	23.6	25.8	28.7	30.1
Buttocks Circumference	847	31.1 - 44.9	36.90±.07	2.13±.05	31.9	33.8	36.7	40.3	42.1
Thigh Circumference	850	17.3 - 28.0	21.88±.06	1.65±.04	18.3	19.3	21.9	24.7	26.1
Calf Circumference	846	10.6 - 16.5	13.42±.03	.98±.02	11.3	11.7	13.2	15.0	15.7
Lower Thigh Circumference	849	12.2 - 18.5	14.79±.04	1.06±.03	12.7	13.2	14.7	16.6	17.5
Ankle Circumference	848	7.1 - 10.2	8.47±.02	.48±.01	7.5	7.8	8.4	9.3	9.7
Arm Scye	851	9.1 - 19.3	14.43±.04	1.19±.03	11.6	12.8	14.5	16.4	17.3
Axillary Arm Circumference	850	8.3 - 14.2	10.99±.03	.95±.02	9.0	9.5	10.9	12.7	13.5
Biceps Circumference (Flexed)	846	7.9 - 14.6	10.50±.03	.88±.02	8.8	9.2	10.5	12.0	12.9
Elbow Circumference (Flexed)	849	7.9 - 15.4	11.22±.04	1.07±.03	8.9	9.6	11.0	13.1	14.2

Note: Dimensions are in inches, unless otherwise noted.
S.D. is standard deviation.

TABLE 21 - 1 (Continued)

Measurement	N	Range	Mean	S.D.	Percentile 1st	5th	50th	95th	99th
Lower Arm Circumference	845	5.9 - 13.0	9.49±.03	.82±.02	7.4	8.3	9.4	10.7	11.6
Wrist Circumference	848	5.1 - 7.9	6.08±.01	.41±.01	5.4	5.5	6.0	6.9	7.3
Sleeve Inseam	845	13.4 - 20.9	17.09±.04	1.03±.03	14.5	15.3	17.2	18.8	19.7
Sleeve Length	849	24.8 - 35.0	29.84±.05	1.57±.04	26.3	27.4	29.9	32.4	33.7
Shoulder Length	846	4.3 - 8.3	6.39±.02	.52±.01	5.2	5.5	6.4	7.3	7.7
Biacromial Arc	843	13.4 - 22.8	18.62±.04	1.28±.03	15.1	16.4	18.6	20.5	21.3
Waist Back	847	11.8 - 19.7	15.51±.04	1.17±.03	13.0	13.8	15.5	17.4	18.7
Waist Front to Cervicale	849	15.7 - 24.0	20.11±.04	1.08±.03	17.2	18.4	20.1	21.9	22.8
Gluteal Arc	839	8.7 - 15.4	11.45±.03	.92±.02	9.6	10.1	11.4	13.1	14.1
Crotch Length	848	19.7 - 33.1	27.42±.07	1.97±.05	22.2	23.9	27.6	30.5	31.7
Vertical Trunk Circumference	845	53.9 - 66.9	59.73±.08	2.44±.08	54.6	55.7	59.4	63.6	65.3
Interscye	847	13.4 - 22.0	17.75±.04	1.27±.03	14.7	15.6	17.7	19.9	21.0
Interscye Maximum	852	14.6 - 22.8	18.81±.04	1.23±.03	15.7	16.8	19.0	21.0	21.8
Hip Circumference (Sitting)	848	32.7 - 48.0	39.22±.08	2.23±.05	34.4	35.9	39.1	43.0	45.6
Knee Circumference (Sitting)	850	11.0 - 19.3	14.68±.04	1.06±.03	12.5	13.2	14.6	16.6	17.8
Foot Length	850	8.0 - 11.4	9.43±.00	.46±.00	8.42	8.74	9.44	10.15	10.48
Instep Length	847	5.5 - 8.1	6.82±.01	.32±.08	6.06	6.30	6.82	7.31	7.52
Foot Width	849	3.0 - 4.4	3.58±.01	.20±.01	3.10	3.24	3.59	3.91	4.01
Heel Width	847	1.5 - 2.3	3.25±.01	.23±.01	1.59	1.84	2.26	2.60	2.73
Ball of Foot Circumference	848	7.5 - 11.0	9.17±.02	.48±.01	8.1	8.4	9.2	10.1	10.5
Hand Length	851	5.9 - 8.2	6.76±.01	.34±.01	6.03	6.23	6.77	7.33	7.64
Hand Breadth at Metacarpale	851	2.5 - 3.8	3.02±.01	.19±.00	2.61	2.72	3.01	3.36	3.56
Hand Breadth at Thumb	844	2.9 - 4.2	3.61±.01	.23±.01	3.08	3.24	3.62	3.99	4.14
Thickness at Metacarpale III	850	.75- 1.4	.97±.00	.09±.00	.81	.84	.96	1.14	1.23
Palm Length	850	2.9 - 4.5	3.74±.01	.25±.01	3.16	3.33	3.73	4.15	4.42
Palm Circumference	851	5.5 - 10.6	7.48±.02	.46±.01	6.6	6.9	7.5	8.1	8.6
Fist Circumference	851	8.3 - 11.4	9.87±.03	.52±.01	8.7	9.1	9.9	10.7	11.0
Head Length	847	5.9 - 7.8	6.84±.01	.30±.01	6.12	6.36	6.87	7.32	7.47
Head Breadth	847	5.2 - 6.5	5.71±.01	.20±.00	5.26	5.38	5.70	6.05	6.21
Head Circumference	847	19.3 - 24.8	21.49±.02	.68±.02	19.99	20.38	21.40	22.68	23.27
Sagittal Arc	852	12.2 - 18.9	14.74±.03	.85±.02	13.0	13.6	14.8	16.6	17.8
Coronal Arc	845	11.8 - 16.1	14.15±.02	.62±.01	12.7	13.0	14.1	15.2	15.7
Posterior Arc	852	8.3 - 19.3	12.45±.04	1.27±.03	9.1	10.6	12.5	14.4	17.3

Note: Dimensions are in inches, unless otherwise noted.
S.D. is standard deviation.

22. Daniels, Gilbert S. and H.T.E. Hertzberg. Applied Anthropometry of the Hand. American Journal of Physical Anthropology, Volume 10, New Series, Number 2, June 1952, pp. 209-215.

"With the advent of high speed aircraft, the need for greater centralization of aircraft control has gradually resulted in the placing of many of the control functions of the fighter airplane directly on the stick grip.

"Previous grips...have been designed by engineers with prime consideration being given to the mechanical nature of the problem. ...The problems of size and comfort, and indeed, operational ease, have generally been considered as secondary design features. We have attempted in the present study to reverse this design procedure by considering first the man who is to use the stick grip. In addition, we have attempted to produce information directly usable by the engineer, and to this end the English system of measurements has been used for all items directly relating to design.

"All the subjects in this study"...(N = 79 except as indicated differently)... "were trained Air Force pilots, and the anthropometric data collected on this series corresponded well to the larger sampling of anthropometric data gathered in the 1950 Air Force Anthropometric Survey... . The hand study group had an average age of 28.9 years compared to 28.8 years for the pilot group of the Anthropometric Survey subjects. Heights and weights were both slightly higher for the smaller group -- 177.5 cm and 171.7 lbs. corresponding to 176.4 cm and 165.7 lbs. for the larger pilot sample. In the Survey these heights and weights were actually measured, while the hand study subjects merely reported them verbally. ...Results of this study are considered applicable to the Air Force pilot population in general. ...We conducted a primary study to determine, first, a 'neutral' position for the mid-sagittal plane of the grip in relation to the centerline of the aircraft at which the combination gripping right hand and stick grip would be so that the wrist would be in a neutral or rest position. Concurrently with this, we gathered data on range of rotation of the hand on the wrist in the cockpit situation." To obtain the necessary measurements on wrist rotation and hand grip contour, two pieces of apparatus were developed. ..."The final evaluation of the grip will be determined by submitting a working model of the proposed grip to a series of pilots for comment."

The article is six pages long, including two tables and four figures. There are no bibliographical references. The data are included in this annotation.

TABLE 22 - 1

Configuration of the Hand in Gripping

	BARE HAND (N = 31)		GLOVED HAND (N = 30)	
	Mean	Range	Mean	Range
Heel of hand width (inches)	1.4	1.1– 1.6	1.3	.8– 1.6
Palm-metacarpal I angle	56.6°	38° –71.3°	60.3°	47° –75°
Metacarpal I length (inches)	1.8	1.1– 2.1	1.8	1.0– 2.4
Metacarpal I — first phalanx I angle	58.4°	45° –73.3°	59.1°	40° –75°
First phalanx I length (inches)	.7	.3– 1.1	...	....
Thumb length (inches)	2.1	1.6– 2.5	...	....

TABLE 22 - 2

Rotation of the Hand on the Wrist

	MEAN [6]	STANDARD DEVIATION	COEFFICIENT OF VARIATION	RANGE OF THE GROUP
Rest or neutral position [1]	19.18° L ± 1.12°	9.95° ± .79°	51.89 ± 4.13	5.3° R to 43° L
Range of motion with control [2]	76.62° ± 2.62°	23.26° ± 1.85°	29.21 ± 2.32	31° to 150°
Control limit left of neutral [3]	45.95° ± 1.76°	15.66° ± 1.25°	34.09 ± 2.71	17° to 86°
Control limit right of neutral	33.61° ± 1.54°	13.66° ± 1.09°	40.66 ± 3.23	6.7° to 67.3°
Extreme range of motion [4]	164.24° ± 2.78°	22.59° ± 1.97°	13.75 ± 1.20	116° to 219°
Extreme limit left of neutral [5]	90.99° ± 2.05°	16.61° ± 1.45°	18.26 ± 1.59	59° to 128.7°
Extreme limit right of neutral	71.82° ± 1.97°	16.03° ± 1.40°	22.32 ± 1.94	44.7° to 119.3°
Control limit left of 0° on measuring device	64.77° L			
Control limit right of 0° on measuring device	14.84° R			
Extreme limit left of 0° on measuring device	110.02° L			
Extreme limit right of 0° on measuring device	54.09° R			

[1] Rest or neutral position: The most comfortable position to the left (L) or to the right (R) of 0° on the measuring device shown in figure 2 or the centerline of the aircraft. The average neutral position of three tries was taken.

[2] Range of motion with control: Total arc in degrees through which subject could *comfortably* move his wrist while still maintaining a usable grip for control of the aircraft.

[3] Control limit left of neutral: }
Control limit right of neutral: } Limit of comfortable and usable control to the left and right respectively of *the individual's own chosen resting position.*

[4] Extreme range of motion: Number of degrees through which subject could *possibly* move his wrist without losing his hold on the grip.

[5] Extreme limit left of neutral: }
Extreme limit right of neutral: } Limit of subject's possible wrist motion to the left and right respectively of *the individual's own chosen resting position.*

[6] The series numbered 79 individuals, except in all cases labeled "Extreme" where N equalled 66.

23. Diehl, Harold S. Height and Weights of American College Men. Human Biology, Volume 5, No. 3, September 1933, pp. 445-479.

This study tabulates and analyzes "the records of the ages and the stripped heights and weights of 23,122 college men (during the academic years 1928-29 and 1929-30), approximately equally distributed among ten colleges and universities in different parts of this country" (Princeton, Yale, Stanford, California, Texas, Minnesota, Cincinnati, Cornell, Wisconsin and the College of the City of New York). "The original purpose of the study was to build tables of average weights, according to age and height, for college students and to compare these averages with those given in the medico-actuarial tables now used as standards. In addition to this, however, these college students have been compared as to height and weight with certain other male groups of the population; and on the same basis the students of the several colleges and universities have been compared to each other.

"Only students from 16 to 21 years of age were included in the tabulations because the numbers of individuals at other ages were relatively small.

"It appears from these studies that college men attain maximum growth in height several years earlier than men in the general population and at each age studied the students are distinctly taller than the men in the groups with which it was possible to compare them; namely, men in citizens' military training camps, applicants for life insurance and army recruits.

"In weight also the college men exceed the men in these other groups, although the relative differences in weight are not so great as the differences in height.

"The table of graded weights according to age and height of the college men shows certain significant differences from the weights given in the medico-actuarial table but, since these differences are less than the standard deviations of individual cases in the various groups from the means of these groups, either table may be considered as reasonably satisfactory for general use, provided that the possibility of normal individual variations is kept in mind." This table is presented in the annotation as "Smoothed Average Weight-College Men."

"Distinct differences exist in the heights and the weights of the several colleges studied. In height, the students of the private colleges, Princeton, Yale and Stanford, exceed those of the state universities and the students of the state universities in turn are taller than the students of the municipal universities studied (College of the City of New York). In weight, a similar general grouping of institutions is found, although a certain amount of shifting of positions of individual colleges and universities occurs.

"The conditions specified were that age should be recorded in years and month or in years to the nearest birthday, that height should be measured without shoes, by means of an arm projecting at a right angle from the vertical plane and sufficiently firm to give accurate readings, that height should be recorded in inches and fractions of an inch; that weight should be recorded in pounds and fractions of a pound. If an examining gown was used the weight of this was deducted from the total weight given."

The article's 34 pages include 13 tables, 10 figures and a bibliography of 21 items. The summary table giving ages, heights, weights and standard deviations, the tables of comparative heights and weights of young American men, and the table of smoothed average weights are included in this annotation.

TABLE 23 - 1

Comparative Heights of Young American Men

AGE	COLLEGE STUDENTS	MEDICO-ACTUARIAL DATA *	MEN IN CITIZENS MILITARY TRAINING CAMPS †	ARMY RECRUITS
16	67.48 ± .08	65.00 ± .11	66.92 ± .03	....
17	68.39 ± .03	66.23 ± .06	67.40 ± .01	....
18	68.72 ± .02	66.81 ± .04	67.79 ± .01	66.90 ± .01
19	68.82 ± .02	67.23 ± .03	68.07 ± .01	66.97 ± .01
20	68.79 ± .03	67.34 ± .03	68.10 ± .02	67.02 ± .02
21	68.77 ± .04	67.50 ± .02	68.16 ± .02	67.33 ± .01

TABLE 23 - 2

Smoothed Average Weight--College Men
(Medico-actuarial Weights in Parenthesis)

HEIGHT	AGE					
	16	17	18	19	20	21
4 feet- 8 inches	94	96	98	100	101	102
4 " - 9 "	97	100	101	104	105	106
4 " -10 "	100	103	104	107	108	109
4 " -11 "	104	106	108	110	111	112
5 " - 0 "	107 (109)	110 (111)	112 (113)	113 (115)	114 (117)	115 (118)
5 " - 1 "	111 (111)	113 (113)	115 (115)	117 (117)	118 (119)	119 (120)
5 " - 2 "	114 (114)	116 (116)	118 (118)	120 (120)	121 (122)	122 (123)
5 " - 3 "	117 (117)	119 (119)	121 (121)	123 (123)	125 (125)	126 (126)
5 " - 4 "	121 (120)	123 (122)	125 (124)	127 (126)	128 (128)	129 (130)
5 " - 5 "	124 (124)	126 (126)	128 (128)	130 (130)	131 (132)	132 (134)
5 " - 6 "	128 (128)	130 (130)	132 (132)	133 (134)	135 (136)	136 (138)
5 " - 7 "	131 (132)	133 (134)	135 (136)	136 (138)	138 (140)	139 (141)
5 " - 8 "	134 (136)	137 (138)	139 (140)	140 (142)	141 (144)	142 (145)
5 " - 9 "	138 (140)	140 (142)	142 (144)	143 (146)	145 (148)	146 (149)
5 " -10 "	141 (144)	144 (146)	145 (148)	146 (150)	148 (152)	149 (153)
5 " -11 "	145 (149)	147 (151)	149 (153)	150 (155)	151 (156)	153 (157)
6 " - 0 "	148 (154)	150 (156)	152 (158)	153 (160)	155 (161)	156 (162)
6 " - 1 "	151 (159)	154 (161)	156 (163)	157 (165)	158 (166)	160 (167)
6 " - 2 "	155 (164)	157 (166)	159 (168)	160 (170)	162 (171)	164 (172)
6 " - 3 "	158 (169)	161 (171)	163 (173)	164 (175)	165 (176)	167 (177)
6 " - 4 "	162 (174)	164 (176)	166 (178)	167 (180)	168 (181)	171 (182)
6 " - 5 "	165 (179)	167 (181)	169 (183)	170 (185)	172 (186)	174 (187)

TABLE 23 - 3

Summary Table--Male Students of All Colleges

AGE	MEAN		STANDARD DEVIATION		PARTIAL STANDARD DEVIATION		$r_{wt.ht.}$	NO. CASES
	Height	Weight	Height	Weight	Of height with weight held constant	Of weight with height held constant		
16	67.48 ± .08	133.70 ± .49	2.89 ± .06	18.11 ± .35	2.43 ± .05	15.23 ± .05	+ .5408 ± .0193	610
17	68.39 ± .03	138.16 ± .21	2.71 ± .02	17.83 ± .15	2.32 ± .02	15.29 ± .02	+ .5140 ± .0087	3244
18	68.72 ± .02	141.09 ± .14	2.64 ± .01	18.08 ± .10	2.29 ± .01	15.67 ± .01	+ .4985 ± .0059	7368
19	68.82 ± .02	142.45 ± .15	2.62 ± .02	17.61 ± .11	2.28 ± .01	15.35 ± .01	+ .4899 ± .0065	6311
20	68.79 ± .03	144.05 ± .20	2.71 ± .02	18.10 ± .14	2.34 ± .02	15.64 ± .02	+ .5037 ± .0084	3613
21	68.77 ± .04	144.87 ± .28	2.56 ± .03	18.48 ± .20	2.22 ± .02	16.06 ± .02	+ .4947 ± .0115	1976
All ages	68.68 ± .01	141.65 ± .08	2.68 ± .01	18.11 ± .06	2.31 ± .01	15.26 ± .01	+ .5056 ± .0033	23122

TABLE 23 - 4

Comparative Weights of Young American Men

AGE	COLLEGE STUDENTS	MEDICO-ACTUARIAL DATA *	MEN IN CITIZENS MILITARY TRAINING CAMPS	ARMY RECRUITS 1906-1915
16	133.70 ± .49	121.71 ± .51	128.09 ± .19	....
17	138.16 ± .21	129.91 ± .27	130.79 ± .07	....
18	141.09 ± .14	135.62 ± .17	134.39 ± .07	134.97 ± .06
19	142.45 ± .15	139.44 ± .13	137.71 ± .09	136.26 ± .08
20	144.05 ± .20	139.77 ± .10	139.85 ± .11	138.13 ± .10
21	144.87 ± .28	141.53 ± .07	140.87 ± .15	141.17 ± .03

* Corrected for weight without shoes or clothing by subtracting 4.46 pounds from the mean weights with clothing as computed from medico-actuarial data.

24. Diehl, Harold S. The Heights and Weights of American College Women. Human Biology, Volume 5, No. 4, December 1933, pp. 600-628.

In this study, age, height and weight data of 17,127 American college women between 16 and 21 years of age have been collected and analyzed.

"The primary purpose of assembling these data was that they might be used to test the suitability of medico-actuarial tables (Medico-Actuarial Investigation. The Association of Life Insurance Medical Directors and the Actuarial Society of America) of 'normal' weights when these are used as standards for college students. The plan of procedure was to build from these data tables of average weights for college students and then to compare these averages with those given in medico-actuarial tables... . For women such data were received from Cornell University, Leland Stanford University, Michigan State Normal College, University of Minnesota, North Carolina College for Women, Smith College, University of Wisconsin and the University of Texas.

"The specifications for the collection of these data for women were that the measurements should have been made during the academic years 1928-29 or 1929-30;

that the students should have been weighed and measured wearing only an examining gown of known weight; that standardized measuring instruments and techniques should have been used; and that measurements should have been recorded according to the method described for college men (Diehl, Harold S. Height and Weights of American College Men.).

"The average height of these college women is 63.75 ± .01 inches; and the average weight, 120.69 ± .09 pounds.

"No growth in either height or weight occurs in these women between the ages of 16 and 21 years.

"College women apparently are taller at least from 16 to 21 years of age than the women from whose heights and weights the medico-actuarial tables were computed. The weights of the college women, however, are lower except at 16 years than the weights given for women in the medico-actuarial tables.

"A comparison of a table of graded average weights of college women with the medico-actuarial table for women indicates that the medico-actuarial table will serve as a reasonably satisfactory standard of weight for college women if the college women are weighed and measured without shoes and clothing. However, if shoes and clothing are included, as they were in life insurance examinations, the medico-actuarial tables become 5 to 10 percent too high for college women. The average increase in the height of 910 University of Minnesota women due to the wearing of shoes was found to be 1.73 ± .01 inches in September 1930, and the average weight of their shoes and clothing to be 2.49 ± .02 pounds.

"The coefficient of variability indicates that approximately one-third of all these college women vary 13 or more per cent from the average, or so-called 'standard', weight. This makes necessary a new definition of 'normal' variability in weight.

"A comparison of the statistical constants for women with those for men indicates that college men are taller and heavier than college women of the same age; that at 16 years of age men are relatively slighter than the women; and that college women reach maximum growth in both height and weight several years earlier than do the men."

The article's 28 pages include 22 tables, three figures and a bibliography of six items. The summary table giving ages, heights, weights and standard deviations, tables of sex differences in heights and weights of college students, and the table of smoothed average weights are included in this annotation.

TABLE 24 - 1

Summary Table--Women Students of All Colleges

AGE	MEAN		STANDARD DEVIATION		PARTIAL STANDARD DEVIATION		$r_{wt.ht.}$	NO. CASES
	Height	Weight	Height	Weight	Of Height with Weight held constant	Of Weight with Height held constant		
16	63.82±.06	120.04±.45	2.27±.04	17.77±.32	2.07±.29	16.17±.29	+.4150±.0211	702
17	63.69±.03	119.85±.19	2.29±.02	16.84±.13	2.11±.12	15.49±.12	+.3922±.0094	3676
18	63.69±.02	120.72±.15	2.34±.01	17.33±.11	2.13±.10	15.74±.10	+.4181±.0072	5901
19	63.86±.02	121.03±.18	2.27±.02	16.71±.13	2.06±.13	16.71±.13	+.4199±.0090	3838
20	63.85±.04	121.74±.27	2.35±.03	17.99±.19	2.11±.17	16.16±.17	+.4398±.0123	1949
21	63.74±.05	120.73±.36	2.33±.03	17.50±.26	2.13±.24	16.26±.24	+.4037±.0173	1061
All ages	63.75±.01	120.69±.09	2.33±.008	17.10±.06	2.11±.06	15.51±.06	+.4215±.0042	17127

TABLE 24 - 2

Smoothed Average Weights--College Women--(Medico-actuarial Weights in Parentheses)

HEIGHT	AGE 16	17	18	19	20	21
4 feet- 8 inches	96 (102)	97 (103)	97 (104)	97 (105)	97 (106)	97 (107)
4 feet- 9 inches	98 (104)	99 (105)	100 (106)	100 (107)	100 (108)	100 (109)
4 feet-10 inches	101 (106)	102 (107)	103 (108)	103 (109)	103 (110)	103 (111)
4 feet-11 inches	104 (108)	105 (109)	106 (110)	106 (111)	106 (112)	106 (113)
5 feet	108 (109)	109 (111)	109 (112)	109 (113)	109 (114)	109 (115)
5 feet- 1 inch	111 (111)	112 (113)	112 (114)	112 (115)	112 (116)	112 (117)
5 feet- 2 inches	114 (114)	115 (116)	115 (117)	115 (118)	115 (119)	115 (120)
5 feet- 3 inches	117 (117)	118 (119)	118 (120)	118 (121)	118 (122)	118 (123)
5 feet- 4 inches	120 (120)	121 (122)	122 (123)	122 (124)	122 (125)	122 (126)
5 feet- 5 inches	124 (124)	124 (125)	125 (126)	125 (127)	126 (128)	126 (129)
5 feet- 6 inches	127 (128)	127 (129)	128 (130)	128 (131)	129 (132)	129 (133)
5 feet- 7 inches	129 (132)	130 (133)	131 (134)	131 (135)	132 (136)	132 (137)
5 feet- 8 inches	132 (136)	133 (137)	134 (138)	135 (139)	136 (140)	136 (141)
5 feet- 9 inches	135 (139)	136 (140)	137 (141)	138 (142)	139 (143)	139 (144)
5 feet-10 inches	138 (143)	139 (144)	140 (145)	141 (146)	142 (147)	142 (148)
5 feet-11 inches	141 (148)	142 (149)	143 (150)	144 (151)	145 (151)	146 (152)
6 feet	144 (153)	145 (154)	146 (155)	147 (155)	148 (156)	149 (156)

TABLE 24 - 3

Average Weights-College Women-Age 21 Years

HEIGHT	MEAN WEIGHT	S. D.	C. V.	CASES Number	Per cent
56	102.50	....	....	2	.19
57	89.00±2.48	8.22±1.75	9.24	5	.47
58	101.67±2.97	7.63±2.10	7.50	3	.28
59	105.94±2.43	14.40±1.72	13.59	16	1.51
60	110.29±1.26	13.34± .89	12.10	51	4.82
61	113.86±1.20	17.86± .85	15.66	101	9.55
62	115.00± .89	15.52± .63	13.50	138	13.04
63	117.98± .71	14.70± .50	12.46	193	18.24
64	122.41± .82	15.72± .58	12.84	166	15.69
65	125.07± .95	17.23± .67	13.78	150	14.18
66	124.40± .99	15.38± .70	12.36	109	10.30
67	132.95±1.30	15.71± .92	11.82	66	6.24
68	131.79±1.89	17.49±1.34	13.27	39	3.69
69	128.57±1.89	10.46±1.33	8.14	14	1.32
70	149.00±4.70	15.57±3.32	10.45	5	.47
71	152.50	....	....	2	.19
72	170	....	....	1	.09
Mean Ht. 63.74±.05	120.73± .36	17.50± .26	14.50	1061	....

TABLE 24 - 4

Sex Differences in Heights and Weights of College Students

A. Height

AGE	COLLEGE MEN MEAN HEIGHT	COLLEGE WOMEN MEAN HEIGHT	DIFFERENCE
16 years	67.48±.08	63.82±.06	3.66±.10
17 years	68.39±.03	63.69±.03	4.70±.04
18 years	68.72±.02	63.69±.02	5.03±.03
19 years	68.82±.02	63.86±.02	5.04±.03
20 years	68.79±.03	63.85±.04	4.94±.05
21 years	68.77±.04	63.74±.05	5.03±.06
All ages	68.68±.01	63.75±.01	4.93±.02

B. Weight

AGE	COLLEGE MEN MEAN WEIGHT	COLLEGE WOMEN MEAN WEIGHT	DIFFERENCE
16 years	133.70±.49	120.04±.45	13.66±.67
17 years	138.16±.21	119.85±.19	18.31±.28
18 years	141.09±.14	120.72±.15	20.37±.21
19 years	142.45±.15	121.03±.18	21.42±.23
20 years	144.05±.20	121.74±.27	22.31±.34
21 years	144.87±.28	120.73±.36	24.14±.45
All ages	141.65±.08	120.69±.09	20.96±.12

25. Geoghegan, Basil. The Height of R.N. Male Personnel. R.N.P. 53/733, O.E.S. 227, Report prepared for the Operational Efficiency Sub-Committee of the Royal Naval Personnel Research Committee, January 1953.

Purpose: To estimate the mean height and the distribution of height in R.N. male personnel.

Subjects: N = 399 men from the complements of H.M. Ships "Excellent", "Gabbard" and "Wave", together with some R.N. personnel on duty at Oxford.

Results:

	Centimeters	Inches
Mean height	172.4	67.9
Standard deviation	6.35	2.5
Truncation point selected	165.95	65.33
N (original sample)	399	
N (after selection)	344	

The distribution of these heights about the mean was found to be truncated. This was mainly due to a limit of height and health standards for R.N. personnel on entering the Service. The solution was to take a point of truncation at 165.95 centimeters. "The necessity of testing for and making the appropriate allowances for a truncated distribution is noted in these data; it is suggested that similar treatments should be required in the analysis of any other body dimension in a Service sample.

"The results closely resemble the height distribution in Kent, the West Country and the Hampshire Basin and less closely resemble or are significantly different from the heights of other population groups in Britain."

"Because of the potential effect of these features in the selection of personnel in the R.N., it seemed advisable to test the sample distribution for truncation. ...As the point of truncation approaches the mean the number available for sampling and the precision with which the mean is estimated decrease, i.e., the standard error of the mean increases. Small differences in the calculated means and standard deviations at the selected points of truncation are due to the relatively small size of the sample and its imperfect distribution about the mean and within the truncation point. The results of truncation at 165.95 cms. (65.33") are selected for use in the following table since, in the first place, this is the highest point of truncation (and theoretically the most accurate) which the data can stand, as moving the point by 2 cms. would involve the loss of a further 9% (making 24% in all) of the data. Secondly, the mean appears to agree closest with the modal value, and thirdly, the values obtained seem to lie between the extremes derived from other points of truncation. The selection of this particular point of truncation is arbitrary and naturally subject to criticism."

This report is 16 pages long, including seven tables, two figures, a 17-item bibliography, and an appendix of statistical formulas. One of the tables follows.

TABLE 25 - 1. Tables of the percentage of R.N. male personnel included within a rounded range (in cms. or inches) about a rounded mean height (172.5 cms. or 68 ins.) where the adjusted mean height is 172.3925 cms. or 67.871 ins. The difference between this percentage and the figure obtained if the sample is considered to be normal (i.e., not truncated) is also given for each rounded range.

	Range	Measurement		%-age included within range	Difference (%-age (sample - truncated sample).	
Cms.	1	172.0 to	173.0	6.28	0.31	Cms.
	2	171.5	173.5	12.50	0.62	
	3	171.0	174.0	18.66	0.91	
	4	170.5	174.5	24.70	1.19	
	5	170.0	175.0	30.60	1.44	
	6	169.5	175.5	36.32	1.68	
	7	169.0	176.0	41.82	1.88	
	8	168.5	176.5	47.10	2.02	
	9	168.0	177.0	52.12	2.17	
	10	167.5	177.5	56.86	2.26	
	11	167.0	178.0	61.32	2.33	
	12	166.5	178.5	65.50	2.35	
	13	166.0	179.0	69.36	2.36	
	14	165.5	179.5	72.94	2.32	
	15	165.0	180.0	76.21	2.26	
	16	164.5	180.5	79.20	2.20	
	17	164.0	181.0	81.90	1.09 2.09	
	18	163.5	181.5	84.32	1.98	
	19	163.0	182.0	86.51	1.84	
	20	162.5	182.5	88.44	1.71	
	21	162.0	183.0	90.14	1.60	
	22	161.5	183.5	91.64	1.42	
	23	161.0	184.0	92.96	1.29	
	24	160.5	184.5	94.09	1.16	
	25	160.0	185.0	95.07	1.01	
Inches	½	67¾	68¼	7.95	0.42	Inches
	1	67½	68½	15.82	0.82	
	1½	67¼	68¾	23.54	1.18	
	2	67	69	31.04	1.51	
	2½	66¾	69¼	38.22	1.80	
	3	66½	69½	45.08	2.04	
	3½	66¼	69¾	51.51	2.25	
	4	66	70	57.54	2.36	
	4½	65¾	70¼	63.10	2.43	
	5	65½	70½	68.17	2.44	
	5½	65¼	70¾	72.78	2.41	
	6	65	71	76.90	2.32	
	6½	64¾	71¼	80.55	2.21	
	7	64½	71½	83.76	2.07	
	7½	64¼	71¾	86.56	1.90	
	8	64	72	88.97	1.72	
	8½	63¾	72¼	91.03	1.52	
	9	63½	72½	92.75	1.36	
	9½	63¼	72¾	94.20	1.17	
	10	63	73	95.39	1.09	

26. Gibbons, Thomas B., Irving A. Phillips, Ronald K. Budensiek and John R. Gilbertson. Age, Height, and Weight of 2173 Men Entering Recruit Training During 1952 at the U.S. Naval Training Center, Great Lakes, Illinois. Project Report NM 003 044.01.01, Naval Medical Research Unit No. 4, Administrative Command, U.S. Naval Training Center, Great Lakes, Illinois, 22 June 1953 (Armed Services Technical Information Agency No. AD-37942).

The report presents some anthropometric statistics on 2173 of the approximately 30,000 males entering the Recruit Training Program during 1952 at the U.S. Naval Training Center, Great Lakes, Illinois. The statistics cover height, weight and chronological age of the Navy recruits measured. Based on the data collected, the report also shows body weight in relation to height and age of the men.

The average recruit entering training was nineteen years old, five feet, eight and one-half inches tall, and weighed 152.4 pounds. Body weights represented, on the average, 105.4 percent of the standard weight for height and age as given in the Medico-Actuarial Report of 1912.

The recruits studied ranged in age from seventeen through twenty-five years, in height from five feet to six feet, six inches, and in weight from 105 to 258 pounds. Relative body weights (actual weight as a per cent of standard weight) were from 74 to 157 per cent.

These figures are compared with previous information obtained on former draft registrants, Army inductees, and Army separatees. In general the 1952 Navy recruits were slightly taller and heavier, the differences being small but significant.

Navy recruits who entered training in 1952 at Great Lakes, Illinois, were taller (by one inch) and heavier (by 10 pounds) than men registering for the 1917-18 draft, but of the same height and weight as men who passed the 1940-41 draft physical examination. This report confirms the concept that midcentury Americans are physically larger than their forefathers.

The Navy recruit of 1952 was slightly taller, on the average, than men separated from the Army in 1946, but weighed less. However, his relative body weight exceeded that of Army inductees observed in 1949.

The subjects were randomly selected throughout the year. The geographical origin of the subjects was chiefly the Midwestern (66.3%) and Middle Atlantic (21.2%) states. Measurements on thirty-five Negroes were included in the totals, but there was no racial separation of data. Height and body weight were recorded in the physical examination given to all incoming recruits.

In the report there are five tables, one graph and a bibliography listing seven references. The following tables present the essential data contained in the report.

27. Gibbons, Thomas B., Irving A. Phillips, Ronald K. Budensiek and John R. Gilbertson. Changes in Body Weight During Recruit Training at the U.S. Naval Training Center, Great Lakes, Illinois. Project Report NM 003 044.02.01, Naval Medical Research Unit No. 4, Administrative Command, U.S. Naval Training Center, Great Lakes, Illinois, 22 June 1953 (Armed Services Technical Information Agency No. AD-37942a).

This report deals with the observed nutritional effects of the training program given to young men entering the Recruit Training Program during 1952 at the U.S. Naval Training Center, Great Lakes, Illinois. The authors selected subjects (N = 2173) at random from approximately 30,000 recruits entering the Recruit Training Program that year. Of these men, 2116 actually completed training with their original company in the prescribed time, serving as the net observed sample for the study. Age, height and weight of the men were the basic data. The report shows the changes in body height and weight that occurred during recruit training. The training period was eleven weeks.

TABLE 26 - 1

Height of 2173 Men Entering Recruit Training During 1952 at the U.S. Naval Training Center, Great Lakes, Illinois.

Height in Inches:	17 %	17 N	18 %	18 N	19 %	19 N	20 %	20 N	21-25 %	21-25 N	Total %	Total N
	Age to Nearest Birth Date											
60	-	-	0.7	4	-	-	-	-	-	-	0.2	4
61	0.4	1	-	-	0.2	1	0.4	2	-	-	0.2	4
62	1.1	3	0.4	2	0.2	1	0.7	3	-	-	0.4	9
63	1.5	4	1.1	6	0.8	5	1.3	6	0.8	2	1.1	23
64	5.3	14	2.5	14	2.2	14	2.6	12	2.1	5	2.7	59
65	10.2	27	7.9	45	5.4	35	4.0	18	3.4	8	6.1	133
66	12.8	34	10.0	57	9.1	59	9.7	44	8.0	19	9.8	213
67	15.0	40	13.0	74	12.7	82	12.3	56	9.7	23	12.7	275
68	14.7	39	15.0	85	15.8	102	15.6	71	13.3	31	15.1	328
69	12.4	33	15.0	86	15.9	103	16.3	74	18.5	44	15.7	340
70	12.4	33	13.2	75	12.7	82	12.1	55	13.5	32	12.8	277
71	6.0	16	10.4	59	11.0	71	9.9	45	13.9	33	10.3	224
72	4.5	12	5.6	32	8.8	57	8.1	37	7.6	18	7.2	156
73	2.3	6	3.0	17	3.9	25	4.0	18	5.5	13	3.6	79
74	0.4	1	1.6	9	1.4	9	2.4	11	2.1	5	1.6	35
75	0.8	2	0.2	1	-	-	0.7	3	0.4	1	0.3	7
76	-	-	0.2	1	-	-	-	-	0.8	2	0.1	3
77	-	-	0.2	1	-	-	-	-	0.8	2	0.1	3
78	0.38	1	-	-	-	-	-	-	-	-	0.1	1
Total	266		568		646		455		238		2173	
Mean	67.9		68.4		68.8		68.7		69.3		68.6	
S.D.	2.57		2.57		2.30		2.54		2.54		2.48	

TABLE 26 - 2

Body Weight of 2173 Men Entering Recruit Training During 1952 at the U.S. Naval Training Center, Great Lakes, Illinois.

Weight in Pounds:	17 %	17 N	18 %	18 N	19 %	19 N	20 %	20 N	21-25 %	21-25 N	Total %	Total N
	Age to Nearest Birth Date											
100-109	1.1	3	0.4	2	-	-	0.7	3	-	-	0.4	8
110-119	5.3	14	4.8	27	1.7	11	2.4	11	3.8	9	3.3	72
120-129	22.9	61	11.3	64	7.6	49	8.1	37	2.5	6	10.0	217
130-139	18.4	49	19.0	108	17.0	110	13.8	63	11.8	28	16.5	358
140-149	20.7	55	20.8	118	20.8	134	25.1	114	19.3	46	21.5	467
150-159	13.5	36	18.8	107	20.6	133	12.5	57	18.1	43	17.3	376
160-169	9.0	24	12.5	71	12.4	80	14.7	67	17.6	42	13.1	284
170-179	4.5	12	4.1	23	8.2	53	8.8	40	13.0	31	7.3	159
180-189	2.6	7	4.1	23	5.7	37	5.9	27	5.5	13	4.9	107
190-199	0.4	1	1.1	6	2.2	14	3.7	17	4.2	10	2.2	48
200-209	1.1	3	0.7	4	1.6	10	2.2	10	2.9	7	1.6	34
210-219	-	-	1.1	6	1.1	7	0.9	4	-	-	0.8	17
220-229	-	-	1.2	7	0.6	4	0.7	3	0.4	1	0.7	15
230-239	-	-	0.2	1	0.6	4	0.2	1	-	-	0.3	6
240-249	0.4	1	0.2	1	-	-	-	-	0.4	1	0.1	3
250-259	-	-	-	-	-	-	0.2	1	0.4	1	0.1	2
Number	266		568		646		455		238		2173	
Mean	143.2		149.5		154.4		155.1		158.7		152.4	
S.D.	19.77		21.74		21.40		22.23		17.87		20.60	

On the average, recruits entering training were nineteen years of age, five feet, eight and one-half inches tall, and weighed 152.4 pounds. The recruits studied ranged in age from seventeen through twenty-five years, in height from five feet to six feet, six inches, and in weight from 105 to 258 pounds.

Random selection of the subjects took place throughout the year. The geographical origin of the subjects was chiefly the Midwestern (66.3%) and Middle Atlantic (21.2%) states. As to the methods of obtaining the data, nude body weight and height were taken of the subjects within two days of arrival at Great Lakes and again within two or three days after completing the training, in accordance with the regular physical examination given to recruits.

The analysis showed that during training, more recruits gained weight than lost, and about one third maintained a constant weight throughout the period. Analysis also revealed that weight gain was most likely to occur in the younger men and in underweight men. Weight losses usually occurred in overweight recruits, especially if over twenty years of age. A seasonal variation in weight occurred, with a tendency to loss of weight in the spring and summer and gain in weight during fall and winter. Body height did not change sufficiently during training to be detected.

Nutritional status of the great majority of men appeared to be improved during recruit training. As the report itself states in conclusion: "The Recruit Training Program of the Navy appears to provide good hygienic living conditions from a physiologic point of view. Caloric intake and expenditure are properly balanced. Since physical culture is not stressed in the training program, the failure of many recruits to gain weight should not be disturbing or unexpected."

In the report are eight tables of data, two graphs and a list of seven references. The results with respect to weight changes in pounds occurring during 11 weeks' training in 2116 recruits are presented in the following table.

TABLE 27 - 1

Weight Changes Occurring During Training of 2116 Men Entering Recruit Training in Year 1952 at the U.S. Naval Training Center, Great Lakes, Illinois.

Weight Change in Pounds		Number of Men	Percent of Total
Gain	25 or more	3	0.14
	20-24.9	6	0.28
	15-19.9	33	1.56
	10-14.9	116	5.48
	5- 9.9	411	19.42
	3- 4.9	252	11.91
Total Gaining		821	38.80
Unchanged ± 3		679	32.09
Total Losing		616	29.11
Loss	3- 4.9	160	7.56
	5- 9.9	239	11.29
	10-14.9	117	5.53
	15-19.9	57	2.69
	20-24.9	20	0.95
	25 or more	23	1.09

28. Gray, Horace. Increase in Stature of American Boys in the Last Fifty Years. Journal of the American Medical Association, Volume 88, No. 12, 19 March 1927, p.908

The purpose of this study was to determine whether or not there had been an increase in the stature of certain American boys over the fifty-year period prior to 1926, and if so how great an increase?

The method considers that "Evidence may be seen by comparing our (the author's) private school boys with as nearly similar a series measured half a century ago as can be found." The three groups utilized are: Bowditch's (Bowditch, H.P. Growth of Children. 10th Annual Report) Sons of American Born Men in Professions (N not given), Bowditch's (Bowditch, H.P. Growth of Children. 8th Report) Sons of American Born Men in Selected Schools (N = 303), and the author's (Gray, Horace and Frederick Fraley. Growth Standards, Height, Chest-Girth and Weight for Private School Boys) 1016 subjects. The subjects are selected groups in the sense that they were "private school" students, i.e., from the Boston Latin Schools and Massachusetts Institute of Technology. The age ranges and stature differences are presented in Figure 28-1.

The author concludes that American-born boys of American-born parents are today taller than boys fifty years ago, as similar as have been found, by more than two inches.

Two figures and five bibliographic items are included.

Age Nearest Year	Height (Cm.) for Age: Bowditch's Sons of American Born Men in Professions	Height (Cm.) for Age: Bowditch's Sons of American Born Men in Selected Schools	Excess in Stature (Cm.) of Our 1,016 Boys over: Column 2	Excess in Stature (Cm.) of Our 1,016 Boys over: Column 3
1	2	3	4	5
6	110.0	.....	9.0	...
7	116.1	.....	8.0	...
8	122.4	.....	7.8	...
9	127.0	.....	8.5	...
10	130.7	.....	9.1	...
11	136.0	137.7	6.7	5.0
12	141.5	141.8	7.7	7.4
13	146.7	147.8	6.1	5.0
14	152.5	153.8	9.5	8.2
15	159.6	159.7	7.9	7.8
16	164.5	165.1	7.7	7.1
17	167.2	169.2	7.3	5.3
18	169.5	.....	7.2	...
All ages, sum			102.5	45.8
All ages, mean			7.9	6.5

FIGURE 28-1. Increase in Stature of American Boys in the Last Fifty Years.

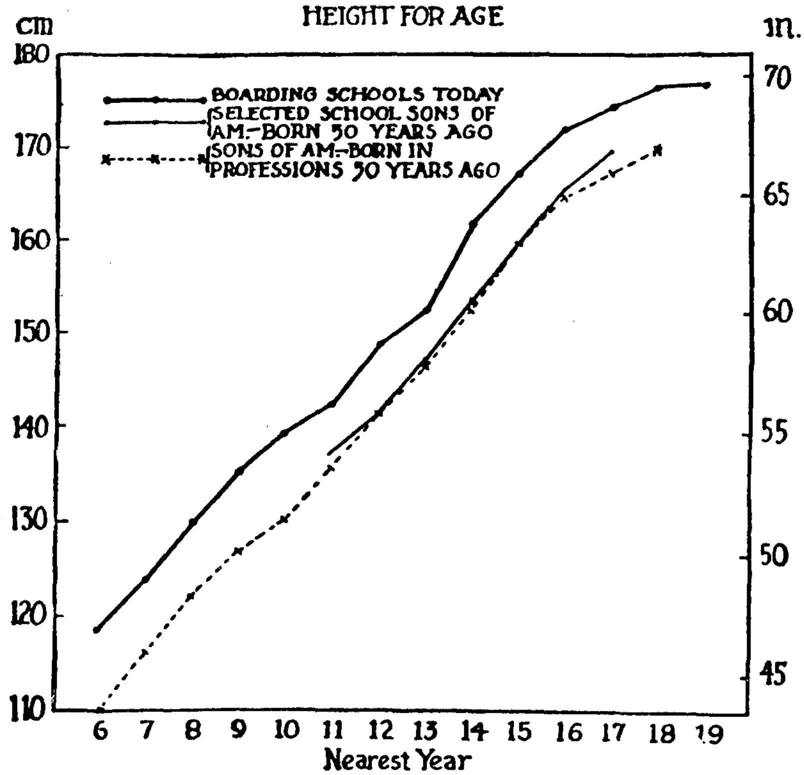


FIGURE 28-2. Stature at Present and Fifty Years Ago.

29. Hertzberg, H.T.E., G.S.Daniels and E. Churchill. Anthropometry of Flying Personnel - 1950. WADC Technical Report 52-321, USAF, Wright Air Development Center, Wright-Patterson Air Force Base, September 1954 (Armed Services Technical Information Agency No. AD-47953).

"Body size data for 132 measurements of over 4,000 Air Force flying personnel are presented for use by the designers of aircraft, clothing and equipment. Organization of the survey is briefly discussed and the techniques of measurement are illustrated by photographs (and drawings) for the benefit of other anthropologists. Both diametral and surface measurements are included. Dimensions are given in both centimeters and inches.

"A description of the statistics and an explanation of their use are given with some discussion of certain statistical shortcuts employed in the reduction of the data. The tabulations include range, mean, standard deviation, coefficient of variation, and twenty-five selected values from the first to the ninety-ninth percentile. Means and standard deviation values for each dimension are also given for nine subgroups based on flight duties."

Distributions of this Air Force sample are presented for Air Force base, rank, religion, education, aero-rating, race and marital status. "Studies of this sample indicate that significant differences in bodily dimensions do exist among men in different aero-ratings, among men born in different regions, and among men stationed at different bases. An examination of the size and nature of these differences suggests two conclusions. First, that these differences are large enough to make essential a broad sampling similar to that used in this survey. Second, that these differences are small enough to justify the conviction that this sample, while undoubtedly not an exact image of the entire Air Force flying personnel, reflects with adequate accuracy the dimensional make-up of the Air Force flying personnel at the time the measuring was done (spring and summer 1950.)" The age range for the sample was 18 to 45 years (plus one man of 54 years), with 98% between 20 and 35 years.

TABLE 29 - 1

Anthropometric Data for U.S. Air Force Flying Personnel - 1950

Measurement	Number of Subjects	Range	Mean	Standard Deviation	Percentiles 1st	5th	50th	95th	99th
Weight									
1. Weight (in pounds)	4052	104. -265.	163.66	20.86	123.1	132.5	161.9	200.8	215.9
Body Lengths									
2. Stature	4062	59.45 - 77.56	69.11	2.44	63.5	65.2	69.1	73.1	74.9
3. Nasal Root Height	4063	56.30 - 73.23	64.95	2.39	59.4	61.0	65.0	68.9	70.7
4. Eye (Internal Canthus) Height	4063	56.30 - 73.23	64.69	2.38	59.2	60.8	64.7	68.6	70.3
5. Tragion Height	4063	54.72 - 74.41	63.92	2.39	58.4	60.0	64.0	67.8	69.6
6. Cervicale Height	4062	50.39 - 66.93	59.08	2.31	53.7	55.3	59.2	62.9	64.6
7. Shoulder (Acromial) Height	4063	47.24 - 64.17	56.50	2.28	51.2	52.8	56.6	60.2	61.9
8. Suprasternale Height	4062	48.03 - 63.78	56.28	2.19	51.3	52.7	56.3	59.9	61.5
9. Nipple Height	4059	42.13 - 57.09	50.41	2.08	45.6	47.0	50.4	53.9	55.3
10. Substernale Height	2950	41.34 - 55.51	48.71	2.02	44.0	45.6	48.7	52.1	53.5
11. Elbow Height (Radiale Height)	4063	36.61 - 49.21	43.50	1.77	39.5	40.6	43.5	46.4	47.7
12. Waist Height	4063	34.65 - 48.82	42.02	1.81	37.7	39.1	42.1	45.0	46.4
13. Penale Height	2951	27.95 - 41.34	34.52	1.75	30.6	31.6	34.5	37.4	38.7
14. Wrist Height (Stylion Height)	4063	27.56 - 39.76	33.52	1.54	30.1	31.0	33.6	36.1	37.1
15. Crotch Height (Inseam)	4062	26.77 - 38.19	32.83	1.73	29.3	30.4	32.8	35.7	37.0
16. Gluteal Furrow Height	4063	25.20 - 37.01	31.57	1.62	27.9	29.0	31.6	34.3	35.5
17. Knuckle (Metacarpale III) Height	4059	24.80 - 35.04	30.04	1.45	26.7	27.7	30.0	32.4	33.5
18. Kneecap (Patella) Height	4060	15.75 - 23.23	20.22	1.03	17.9	18.4	20.2	21.9	22.7
19. Sitting Height	4061	29.92 - 40.16	35.94	1.29	32.9	33.8	36.0	38.0	38.9
20. Eye (Internal Canthus) Height,-S	4061	26.38 - 36.61	31.47	1.27	28.5	29.4	31.5	33.5	34.4
21. Shoulder (Acromial) Height,-S	4057	18.90 - 27.17	23.26	1.14	20.6	21.3	23.3	25.1	25.8
22. Waist Height, Sitting	4062	6.30 - 12.99	9.24	.76	7.4	7.9	9.3	10.4	10.9
23. Elbow Rest Height, Sitting	4063	4.33 - 12.99	9.12	1.04	6.6	7.4	9.1	10.8	11.5
24. Thigh Clearance Height,-S	4061	3.94 - 7.09	5.61	.52	4.5	4.8	5.6	6.5	6.8
25. Knee Height, Sitting	4060	17.32 - 24.80	21.67	.99	19.5	20.1	21.7	23.3	24.0
26. Popliteal Height, Sitting	4059	14.17 - 19.29	16.97	.77	15.3	15.7	17.0	18.2	18.8
27. Buttock-Knee Length	4060	18.50 - 27.56	23.62	1.06	21.2	21.9	23.6	25.4	26.2
28. Buttock-Leg Length	4060	35.43 - 50.00	42.70	2.04	38.2	39.4	42.7	46.1	47.7
29. Shoulder-Elbow Length	4059	11.42 - 18.11	14.32	.69	12.8	13.2	14.3	15.4	15.9
30. Forearm-Hand Length	4059	15.35 - 22.05	18.86	.81	17.0	17.6	18.9	20.2	20.7
31. Span	4058	58.27 - 82.28	70.80	2.94	63.9	65.9	70.8	75.6	77.6
32. Arm Reach From Wall	4062	27.56 - 39.76	34.59	1.65	30.9	31.9	34.6	37.3	38.6
33. Maximum Reach From Wall	4055	31.10 - 46.06	38.59	1.90	34.1	35.4	38.6	41.7	43.2
34. Functional Reach	4053	26.77 - 40.55	32.33	1.63	28.8	29.7	32.3	35.0	36.4

Notes: All dimensions in inches, unless otherwise noted.
-S = Sitting

TABLE 29 - 1 (Continued)

Measurement	Number of Subjects	Range	Mean	Standard Deviation	Percentiles 1st	5th	50th	95th	99th
Body Breadths and Thicknesses									
35. Elbow-to-Elbow Breadth	4060	11.42 - 23.62	17.28	1.42	14.5	15.2	17.2	19.8	20.9
36. Hip Breadth, Sitting	4058	11.42 - 18.11	13.97	.87	12.2	12.7	13.9	15.4	16.2
37. Knee-to-Knee Breadth,-S	4056	6.30 - 10.24	7.93	.52	7.0	7.2	7.9	8.8	9.4
38. Biacromial Diameter	4063	12.60 - 18.50	15.75	.74	14.0	14.6	15.8	16.9	17.4
39. Shoulder Breadth(Bideltoid Dia.)	4057	14.57 - 22.83	17.88	.91	15.9	16.5	17.9	19.4	20.1
40. Chest Breadth	4058	9.45 - 15.35	12.03	.80	10.4	10.8	12.0	13.4	14.1
41. Waist Breadth	4063	7.87 - 15.35	10.66	.94	8.9	9.4	10.6	12.3	13.3
42. Hip Breadth	4062	8.27 - 15.75	13.17	.73	11.3	12.1	13.2	14.4	15.2
43. Chest Depth	4063	6.69 - 12.99	9.06	.75	7.6	8.0	9.0	10.4	11.1
44. Waist Depth	4062	5.51 - 11.81	7.94	.88	6.3	6.7	7.9	9.5	10.3
45. Buttock Depth	4058	6.30 - 11.81	8.81	.82	7.2	7.6	8.8	10.2	10.9
Circumferences and Body Surface Measurements									
46. Neck Circumference	4041	10.24 - 19.29	14.96	.74	13.3	13.8	14.9	16.2	16.8
47. Shoulder Circumference	4053	35.43 - 56.69	45.25	2.43	40.2	41.6	45.1	49.4	51.5
48. Chest Circumference	4057	31.10 - 49.61	38.80	2.45	33.7	35.1	38.7	43.2	44.8
49. Waist Circumference	4059	24.41 - 47.24	32.04	3.02	26.5	27.8	31.7	37.5	40.1
50. Buttock Circumference	4049	29.92 - 46.85	37.78	2.29	33.0	34.3	37.7	41.8	43.5
51. Thigh Circumference	4051	14.57 - 28.74	22.39	1.74	18.3	19.6	22.4	25.3	26.4
52. Lower Thigh Circumference	4060	11.81 - 23.23	17.33	1.41	14.2	15.1	17.3	19.6	20.9
53. Calf Circumference	4048	9.84 - 18.50	14.40	.96	12.2	12.9	14.4	16.0	16.7
54. Ankle Circumference	4061	7.09 - 12.99	8.93	.57	7.8	8.1	8.9	9.8	10.5
55. Scye Circumference	4060	11.02 - 22.83	18.09	1.38	15.1	16.1	18.0	20.5	21.8
56. Axillary Arm Circumference	4060	7.87 - 16.54	12.54	1.10	10.2	10.9	12.4	14.4	15.2
57. Biceps Circumference-F	4063	8.27 - 16.93	12.79	1.07	10.5	11.2	12.8	14.6	15.4
58. Elbow Circumference-F	4062	8.27 - 15.35	12.26	.80	10.7	11.1	12.2	13.6	14.3
59. Lower Arm Circumference-F	4059	8.66 - 15.35	11.50	.73	9.9	10.4	11.5	12.7	13.3
60. Wrist Circumference	4057	3.94 - 8.27	6.85	.40	6.0	6.3	6.8	7.5	7.8
61. Sleeve Inseam	4052	15.35 - 24.80	19.83	1.14	17.1	18.0	19.8	21.7	22.6
62. Sleeve Length (Spine-to-Wrist)	4048	27.56 - 38.98	33.64	1.50	30.2	31.3	33.7	36.0	37.3
63. Anterior Neck Length	4063	1.38 - 5.31	3.40	.64	1.8	2.3	3.4	4.4	4.9
64. Posterior Neck Length	4062	1.57 - 6.10	3.64	.61	2.3	2.7	3.6	4.7	5.2
65. Shoulder Length	4048	4.33 - 8.66	6.77	.56	5.5	5.9	6.8	7.7	8.1
66. Waist Back	4062	11.81 - 22.83	17.72	1.07	14.8	16.1	17.7	19.4	20.2
67. Waist Front	4043	10.63 - 21.26	15.24	1.12	12.3	13.5	15.2	17.0	18.1

Notes: All dimensions in inches, unless otherwise noted.
-S = Sitting
Dia. = Diameter
-F = Flexed.

TABLE 29 - 1 (Continued)

Measurement	Number of Subjects	Range	Mean	Standard Deviation	1st	5th	50th	95th	99th
68. Gluteal Arc	4057	7.87 - 17.32	11.71	.92	9.7	10.4	11.7	13.1	14.8
69. Crotch Length	4058	20.08 - 38.19	28.20	2.00	23.7	25.1	28.2	31.6	33.5
70. Vertical Trunk Circumference	4060	54.72 - 74.41	64.81	2.88	58.3	60.2	64.8	69.7	71.7
71. Interscye	4061	12.20 - 24.41	19.62	1.40	16.3	17.3	19.6	22.0	22.9
72. Interscye Maximum	4058	17.72 - 27.17	22.85	1.33	19.8	20.7	22.9	25.1	26.0
73. Buttock Circumference, Sitting	4062	33.46 - 52.36	41.74	2.82	36.1	37.4	41.5	46.7	49.3
74. Knee Circumference, Sitting	4059	11.42 - 20.47	15.39	.92	13.5	14.0	15.4	16.9	17.7
The Foot									
75. Foot Length	4063	8.86 - 12.24	10.50	.45	9.5	9.8	10.5	11.3	11.6
76. Instep Length	4063	6.42 - 8.86	7.64	.34	6.9	7.1	7.6	8.2	8.4
77. Foot Breadth	4060	3.19 - 4.65	3.80	.19	3.40	3.50	3.78	4.10	4.36
78. Heel Breadth	4061	2.13 - 3.27	2.64	.15	2.30	2.40	2.63	2.87	3.01
79. Bimalleolar Breadth	4063	2.44 - 3.58	2.95	.15	2.61	2.70	2.95	3.19	3.32
80. Medial Malleolus Height	4062	2.60 - 4.29	3.45	.21	3.0	3.1	3.5	3.8	4.0
81. Lateral Malleolus Height	4063	2.01 - 3.70	2.73	.22	2.2	2.4	2.7	3.1	3.3
82. Ball of Foot Circumference	4050	7.87 - 12.60	9.65	.48	8.6	8.9	9.6	10.4	10.8
The Hand									
83. Hand Length	4063	5.87 - 8.74	7.49	.34	6.7	6.9	7.5	8.0	8.3
84. Palm Length	4062	3.39 - 5.04	4.24	.21	3.77	3.89	4.24	4.60	4.74
85. Hand Breadth at Thumb	4062	3.23 - 4.76	4.07	.21	3.59	3.73	4.08	4.42	4.57
86. Hand Breadth at Metacarpale	4058	2.99 - 4.09	3.48	.16	3.12	3.22	3.49	3.74	3.86
87. Thickness at Metacarpale III	4061	.75 - 1.54	1.17	.07	1.00	1.05	1.17	1.28	1.35
88. First Phalanx III Length	2955	2.21 - 3.07	2.67	.12	2.40	2.49	2.67	2.85	2.95
89. Finger Diameter III	4063	.75 - 1.00	.86	.05	.77	.79	.85	.93	.96
90. Grip Diameter (Inside)	4062	1.37 - 2.63	1.90	.14	1.52	1.62	1.83	2.05	2.16
91. Grip Diameter (Outside)	4063	3.15 - 4.72	4.09	.21	3.58	3.72	4.09	4.44	4.57
92. Fist Circumference	4053	7.09 - 13.39	11.56	.57	10.2	10.7	11.6	12.4	12.8
The Head and Face									
93. Head Length	4063	6.89 - 8.78	7.76	.25	7.2	7.3	7.7	8.2	8.3
94. Head Breadth	4059	5.35 - 6.89	6.07	.20	5.61	5.74	6.01	6.40	6.56
95. Minimum Frontal Diameter	4061	3.54 - 5.00	4.35	.19	3.88	4.04	4.35	4.68	4.80
96. Maximum Frontal Diameter	4059	4.02 - 5.47	4.71	.20	4.26	4.39	4.72	5.05	5.20
97. Bizygomatic Diameter	4061	4.72 - 6.22	5.55	.20	5.07	5.21	5.54	5.88	6.02
98. Bigonial Diameter	4060	3.50 - 5.08	4.27	.22	3.8	3.9	4.3	4.6	4.8
99. Bitragion Diameter	4060	4.76 - 6.30	5.60	.21	5.1	5.3	5.6	5.9	6.1
100. Interocular Diameter	4055	.87 - 1.65	1.25	.10	1.03	1.09	1.25	1.42	1.50
101. Biocular Diameter	4061	3.19 - 4.45	3.78	.17	3.38	3.48	3.78	4.06	4.19
102. Interpupillary Distance	4057	2.01 - 2.99	2.49	.14	2.19	2.27	2.49	2.74	2.84

Note: All dimensions in inches, unless otherwise noted.

TABLE 29 - 1 (Continued)

Measurement	Number of Subjects	Range	Mean	Standard Deviation	Percentiles 1st	5th	50th	95th	99th
103. Nose Length	4061	1.46 - 2.56	2.01	.14	1.69	1.79	2.00	2.23	2.33
104. Nose Breadth	4058	.91 - 1.85	1.31	.11	1.09	1.16	1.31	1.49	1.58
105. Nasal Root Breadth	4054	.28 - .91	.61	.08	.42	.48	.61	.74	.81
106. Nose Protrusion	4063	.43 - 1.42	.89	.11	.63	.72	.90	1.08	1.17
107. Philtrum Length	4063	.35 - 1.46	.77	.14	.48	.54	.76	.98	1.09
108. Menton-Subnasale Length	4062	1.81 - 3.54	2.63	.27	2.05	2.19	2.62	3.07	3.28
109. Menton-Crinion Length	3555	6.18 - 8.58	7.36	.36	6.6	6.8	7.4	8.0	8.2
110. Lip-to-Lip Distance	4059	.16 - 1.26	.64	.12	.35	.44	.63	.83	.94
111. Lip Length (Bichelion Diameter)	4062	1.34 - 2.64	2.03	.14	1.72	1.81	2.02	2.27	2.38
112. Ear Length	4062	1.69 - 3.15	2.47	.16	2.08	2.21	2.47	2.73	2.85
113. Ear Breadth	4060	1.10 - 1.93	1.44	.11	1.20	1.27	1.44	1.61	1.70
114. Ear Length above Tragion	4061	.79 - 1.61	1.17	.11	.92	.99	1.17	1.35	1.42
115. Ear Protrusion	4063	.31 - 1.54	.84	.14	.55	.63	.83	1.10	1.23
116. Head Height (Tragion to Vertex)	4061	3.90 - 6.26	5.11	.30	4.4	4.6	5.1	5.6	5.8
117. Menton Projection	4063	.98 - 2.83	1.88	.26	1.3	1.5	1.9	2.3	2.5
118. External Canthus to Wall	4062	5.51 - 7.91	6.78	.32	6.0	6.2	6.8	7.3	7.5
119. Nasal Root to Wall	4063	6.54 - 9.02	7.75	.34	7.0	7.2	7.8	8.3	8.5
120. Tragion to Wall	4063	3.07 - 5.20	4.03	.30	3.4	3.5	4.0	4.5	4.8
121. Larynx to Wall	4062	5.35 - 8.62	6.95	.47	5.8	6.2	6.9	7.7	8.0
122. Head Circumference	4056	20.08 - 24.41	22.47	.62	21.0	21.5	22.5	23.5	24.3
123. Sagittal Arc	4063	11.42 - 16.93	15.07	.61	13.6	14.1	15.1	16.0	16.5
124. Bitragion-Coronal Arc	4059	11.81 - 15.35	13.83	.51	12.7	13.0	13.8	14.7	15.1
125. Minimum Frontal Arc	4049	3.94 - 6.69	5.44	.40	4.5	4.8	5.4	6.1	6.3
126. Bitragion-Minimum Frontal Arc	4055	9.84 - 15.35	12.05	.44	11.1	11.4	12.0	12.8	13.1
127. Bitragion-Crinion Arc	3688	11.02 - 15.35	13.10	.53	12.0	12.3	13.1	14.0	14.4
128. Bitragion-Menton Arc	4062	10.63 - 14.57	12.78	.50	11.6	12.0	12.8	13.6	14.0
129. Bitragion-Submandibular Arc	4063	8.66 - 14.57	12.08	.62	10.7	11.1	12.1	13.1	13.7
130. Bitragion-Subnasale Arc	4056	9.84 - 12.99	11.45	.43	10.5	10.7	11.4	12.2	12.4
131. Bitragion-Posterior Arc	4061	7.87 - 12.60	10.71	.48	9.7	10.0	10.7	11.5	11.9
132. Bitragion-Inion Arc	4059	9.84 - 14.57	11.62	.55	10.5	10.8	11.6	12.6	13.0

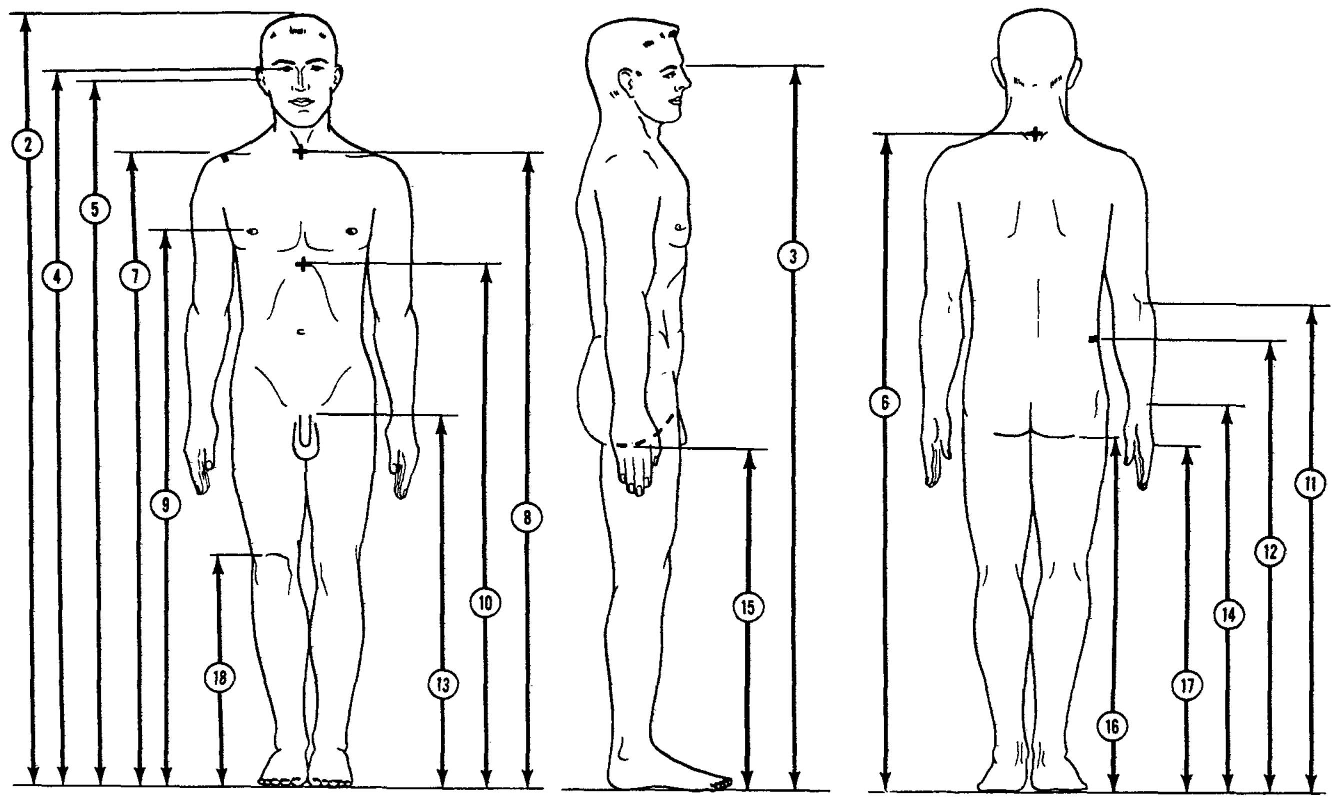
Note: All dimensions in inches, unless otherwise noted.

WEIGHT

1. Weight (Not Shown)

BODY LENGTHS I

2. Stature
3. Nasal Root Height
4. Eye Height (Internal Canthus Height)
5. Tragion Height
6. Cervicale Height
7. Shoulder Height (Acromial Height)
8. Suprasternale Height
9. Nipple Height
10. Substernale Height
11. Elbow Height
12. Waist Height
13. Penale Height
14. Wrist Height
15. Crotch Height (Inseam)
16. Gluteal Furrow Height
17. Knuckle Height
18. Kneecap Height



BODY LENGTHS (SITTING)

19. Sitting Height
20. Eye Height (Internal Canthus Height), S
21. Shoulder Height (Acromial Height), S
22. Waist Height, S
23. Elbow Rest Height, S
24. Thigh Clearance Height, S
25. Knee Height, S
26. Popliteal Height, S
27. Buttock-Knee Length
28. Buttock-Leg Length
29. Shoulder-Elbow Length
30. Forearm-Hand Length

BODY LENGTHS (REACHES)

31. Span
32. Arm Reach from Wall
33. Maximum Reach from Wall
34. Functional Reach

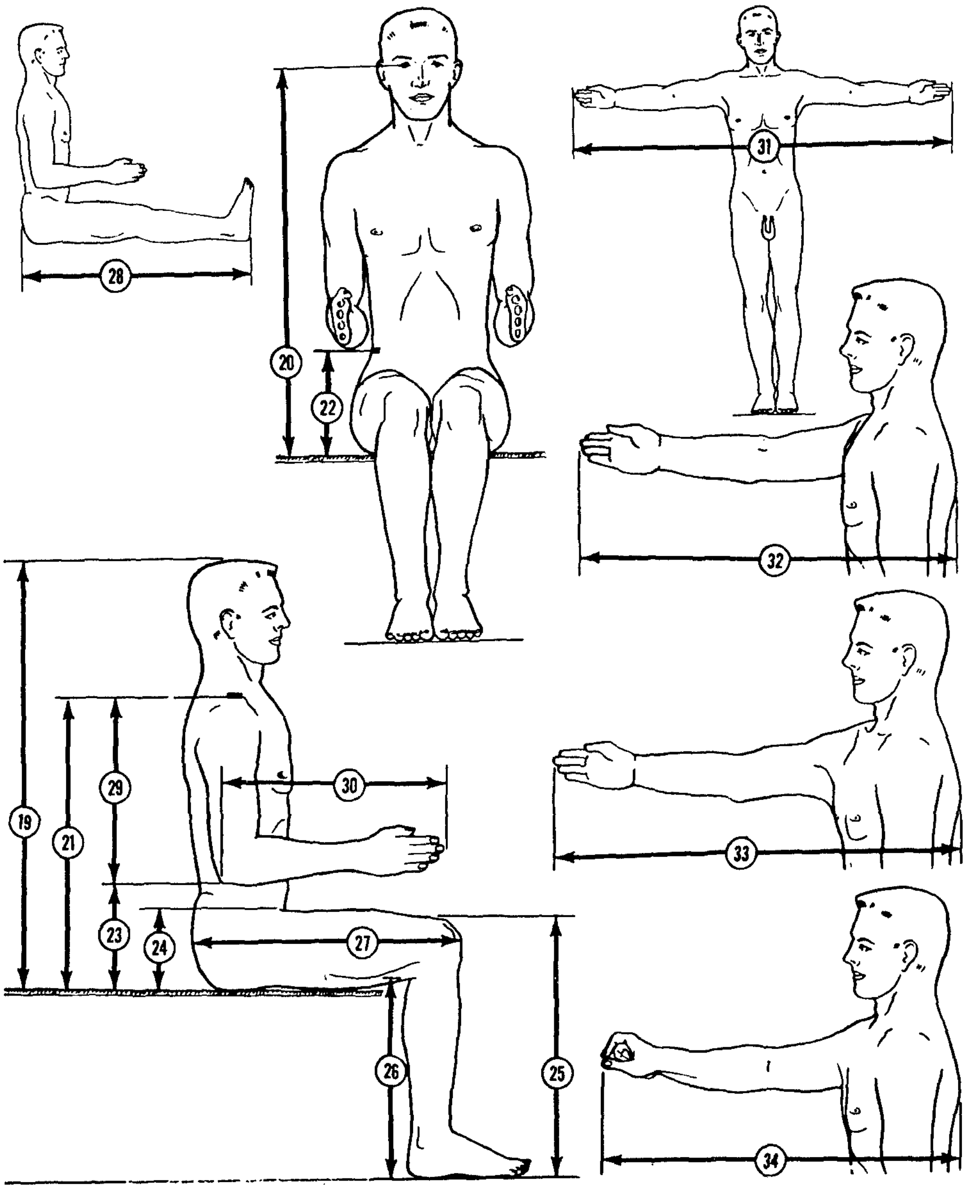


FIGURE 29 - 2

BODY BREADTHS AND THICKNESSES

35. Elbow-to-Elbow Breadth
36. Hip Breadth, S
37. Knee-to-Knee Breadth, S
38. Biacromial Diameter
39. Shoulder Breadth (Bideltoid Diameter)
40. Chest Breadth
41. Waist Breadth
42. Hip Breadth
43. Chest Depth
44. Waist Depth
45. Buttock Depth

CIRCUMFERENCES AND BODY SURFACE MEASUREMENTS

46. Neck Circumference
47. Shoulder Circumference
48. Chest Circumference
49. Waist Circumference
50. Buttock Circumference
51. Thigh Circumference
52. Lower Thigh Circumference
53. Calf Circumference
54. Ankle Circumference
60. Wrist Circumference

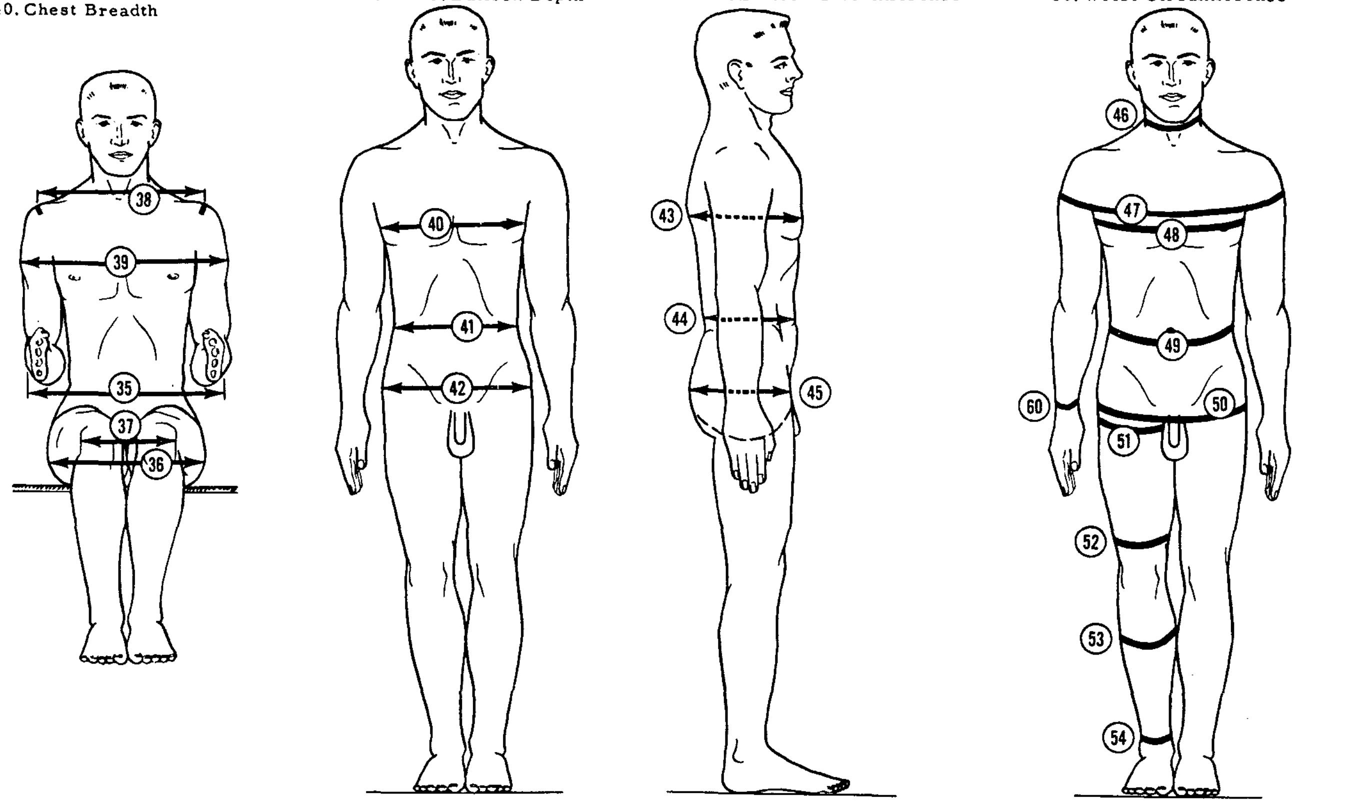


FIGURE 29 - 3

CIRCUMFERENCES AND BODY SURFACE MEASUREMENTS II

55. Scye Circumference
56. Axillary Arm Circumference
57. Biceps Circumference (Flexed)
58. Elbow Circumference (Flexed)
59. Lower Arm Circumference (Flexed)
60. (See preceding page)
61. Sleeve Inseam
62. Sleeve Length (Spine-to-Wrist)
63. Anterior Neck Length
64. Posterior Neck Length
65. Shoulder Length
66. Waist Back
67. Waist Front
68. Gluteal Arc
69. Crotch Length
70. Vertical Trunk Circumference
71. Interscye
72. Interscye Maximum
73. Buttock Circumference, S
74. Knee Circumference, S

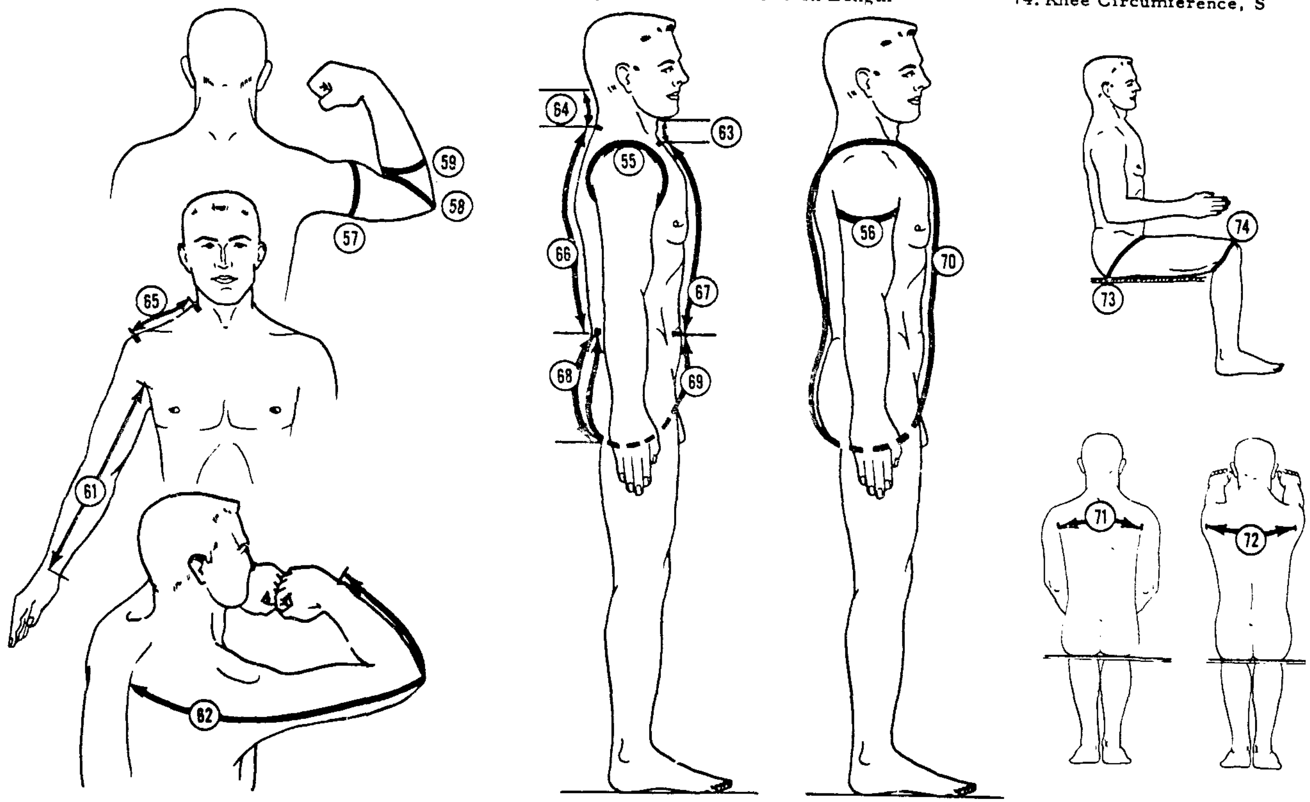


FIGURE 29 - 4

THE FOOT

75. Foot Length
76. Instep Length
77. Foot Breadth
78. Heel Breadth
79. Bi-Malleolar Breadth
80. Medial Malleolus Height
81. Lateral Malleolus Height
82. Ball of Foot Circumference

THE HAND

83. Hand Length
84. Palm Length
85. Hand Breadth at Thumb
86. Hand Breadth at Metacarpale
87. Thickness at Metacarpale III
88. First Phalanx III Length
89. Finger Diameter III
90. Grip Diameter (Inside)
91. Grip Diameter (Outside)
92. Fist Circumference

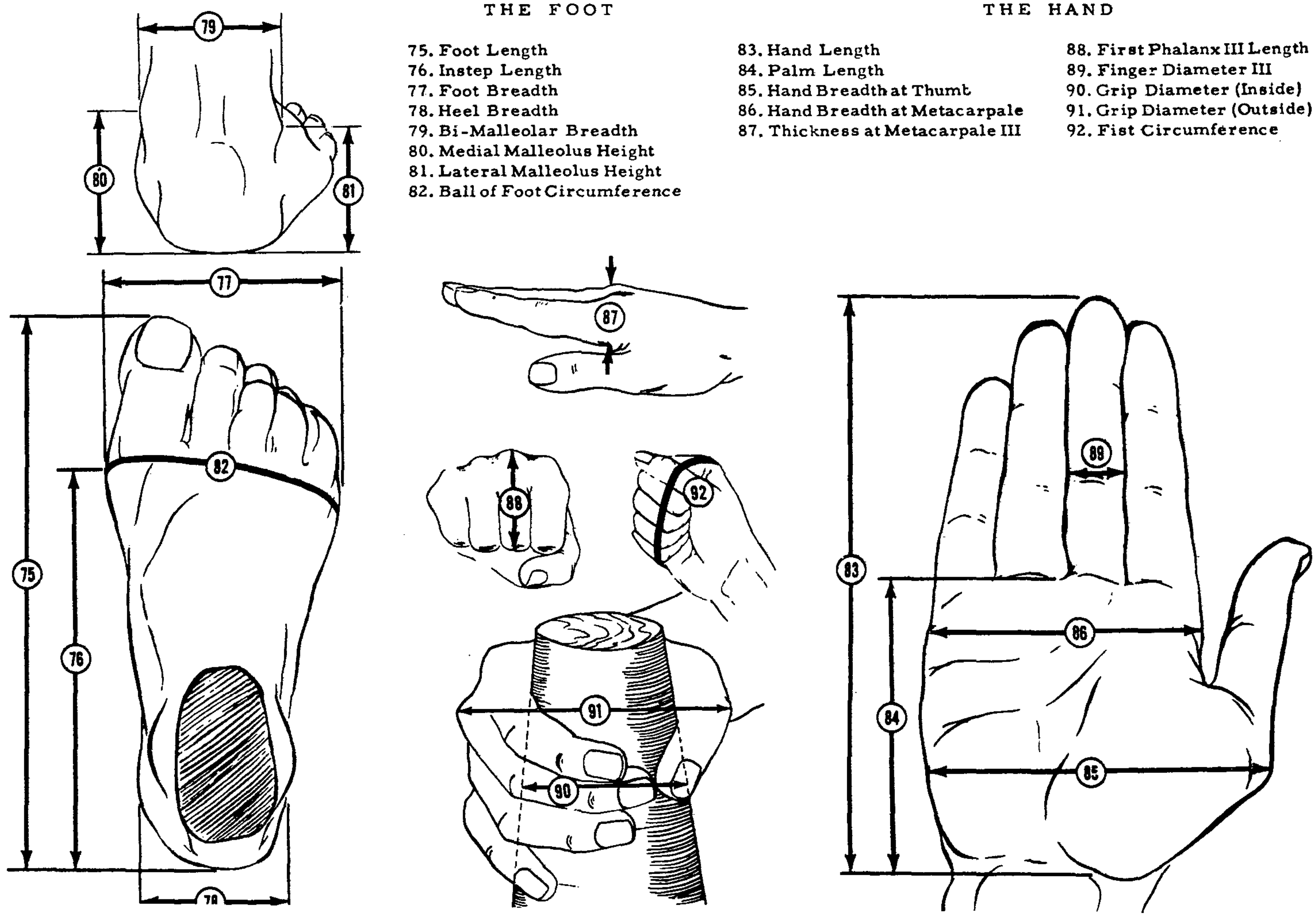


FIGURE 29 - 5

HEAD AND FACE MEASUREMENTS

93. Head Length
94. Head Breadth
95. Min. Frontal Diameter
96. Max. Frontal Diameter
97. Bizygomatic Diameter
98. Bigonial Diameter
99. Bitragion Diameter
100. Interocular Diameter
101. Biocular Diameter
102. Interpupillary Distance
103. Nose Length
104. Nose Breadth
105. Nasal Root Breadth
106. Nose Protrusion
107. Philtrum Length
108. Menton-Subnasale Length
109. Menton-Crinion Length
110. Lip-to-Lip Distance
111. Lip Length (Bichelion Dia.)
112. Ear Length
113. Ear Breadth
114. Ear Length above Tragion
115. (See next page)
116. Head Height (Tragion to Vertex)
117. Menton Projection

125. Minimum Frontal Arc

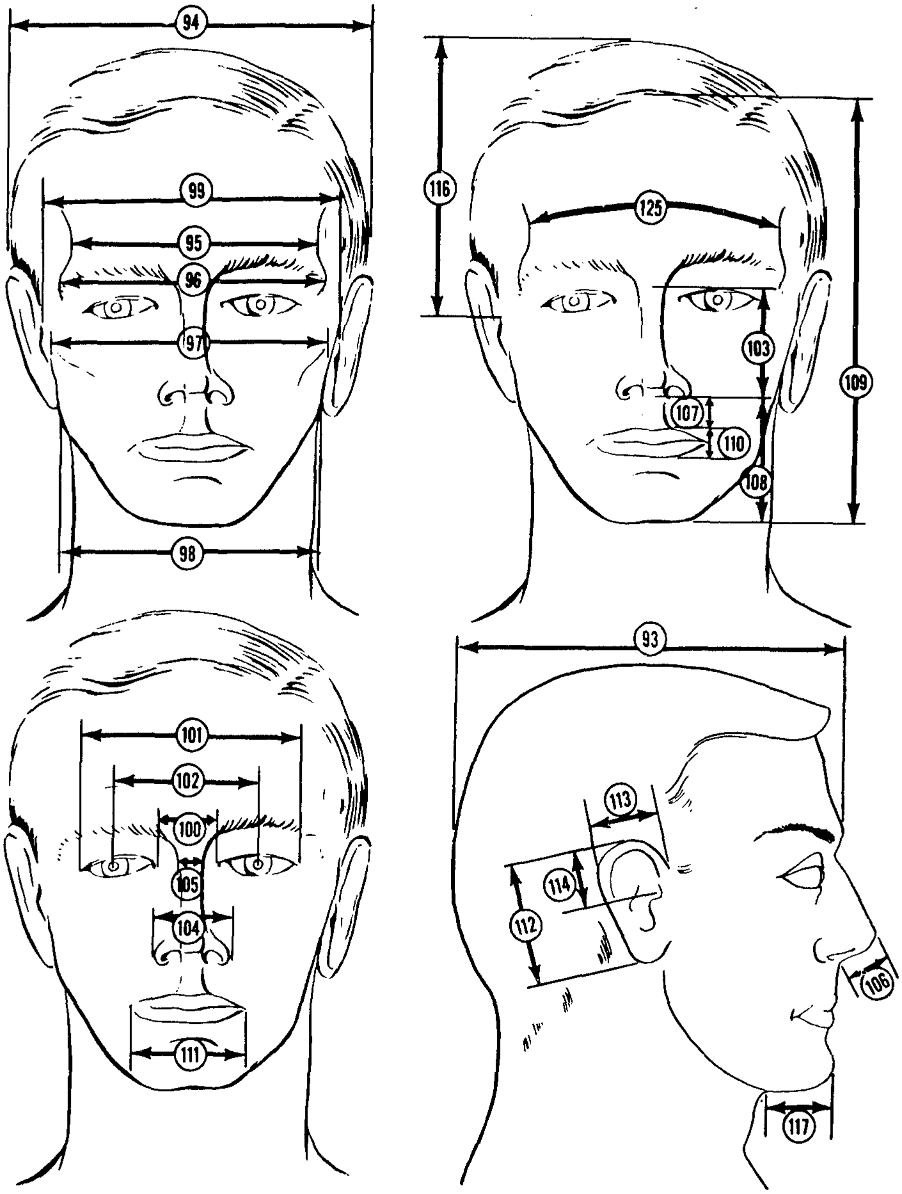


FIGURE 29 - 6

HEAD AND FACE MEASUREMENTS II

115. Ear Protrusion

118. External Canthus to Wall
119. Nasal Root to Wall
120. Tragion to Wall
121. Larynx to Wall

122. Head Circumference
123. Sagittal Arc
124. Bitragion-Coronal Arc
125. (See preceding page)
126. Bitragion-Min. Frontal Arc
127. Bitragion-Crinion Arc

128. Bitragion-Menton Arc
129. Bitragion-Submandibular Arc
130. Bitragion-Subnasale Arc
131. Posterior Arc
132. Bitragion-Inion Arc

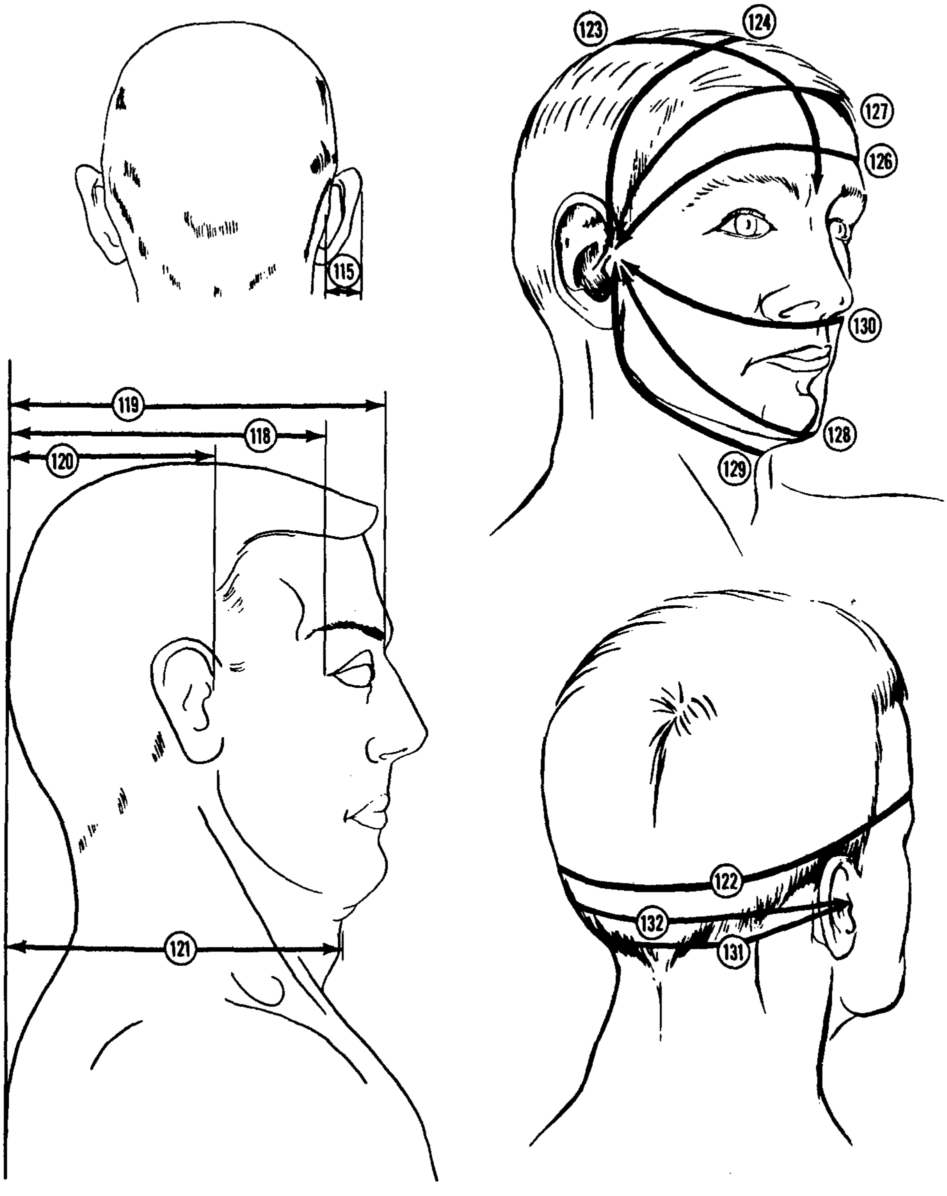


FIGURE 29 - 7

"A Glossary and Bibliography are included."

The table and figures included with this annotation present essential data from this report.

Editor's note: It must be pointed out that the data are taken from a sample highly selected by several mutually opposed criteria, and therefore do not specifically represent the U.S. population at large. The data are intended only for the solution of sizing problems relating to the Air Force population. They must be used with caution in applications intended for a different population. Probably the best modern data representing the (U.S.) population as a whole can be found in the U.S. Quartermaster reports (Quartermaster Corps, U.S. Army. Survey of Body Size of Army Personnel, Male and Female (1946): Body Dimensions of Army Females. Quartermaster Corps, U.S. Army. Survey of Body Size of Army Personnel, Male and Female (1946): Body Dimensions of Army Males.

30. MacKinnon, D.C. and C.M. Jackson. Changes in the Physical Measurements of the Male Students at the University of Minnesota During the Last Thirty Years. The American Journal of Anatomy, Volume 47, No. 2, March 1931, pp. 405-423.

"Statistical studies were made on age, stature, body weight, and vital capacity of 1205 male entrants at the University of Minnesota in 1898-1901 and 1810 entrants in 1929. These two groups were compared to ascertain the changes in physique during this period.

"During this thirty-year period, the average stature shows a significant increase of 19.2 mm (0.8 inch). Body weight simultaneously increased 1.76 kg. (3.9 pounds), which is also statistically significant. Likewise, vital capacity shows a significant increase of 168 cc. These increases are still more impressive, since there is a corresponding decrease of 1.669 years in average age. ...There is but little difference in body build between the earlier and the later group... .

"There is no significant correlation between stature and age, except to a slight extent in the earlier (1898-1901) group. Body weight and age have a low but significant correlation. There is a relatively high correlation between stature and weight. Body weight and age were better correlated in 1898-1901 than in 1929.

"The measurements were taken without clothing. Age was originally recorded in years at the nearest birthday. Stature (standing height) was measured with the subject standing erect on a horizontal plane surface, arms pendent, heels in contact, axis of vision horizontal, with back to wall, upon which a vertical scale is placed. The readings from soles of feet to vertex were taken to 1/10 inch. Body weight was taken to 1/10 pound on a standard scale. The vital capacity was measured to 1 cubic inch with a standard water spirometer. The students were given two or three trials and the maximum reading was recorded."

For the 1929 data, age was recorded as before. Stature was measured to 1/4 inch. Body weight was taken to 1/4 pound on a standard Howe scale. The vital capacity was measured in cubic centimeters with a Sanborn water spirometer, with two or three trials as above. No corrections were made for temperature or barometric pressure.

A summary table of the data for both groups is included in the annotation. The age range for the earlier group was 16 to 41 years, for the 1929 group, 15 to 44 years. The discussion includes comments about findings similar to those of this study, among other American and European groups.

The article includes four tables and a bibliography of 30 references.

TABLE 30 - 1

Statistical Constants for the Two Groups of Male Students Entering the University of Minnesota

MEASUREMENTS	1898–1901 GROUP (1205 CASES)	1929 GROUP (1810 CASES)
Age (years):		
Mean	21.849 ± .064	20.180 ± .038
Standard deviation	3.280 ± .045	2.411 ± .027
Coefficient of variation	15.057 ± .212	11.945 ± .136
Stature:		
Mean	68.194 ± .046 in.	68.949 ± .039 in.
	1732.1 ± 1.2 mm.	1751.3 ± 1.0 mm.
Standard deviation	2.370 ± .033 in.	2.458 ± .028 in.
	60.44 ± .83 mm.	62.43 ± .7
Coefficient of variation	3.480 ± .048	3.565 ± .040
Body weight:		
Mean	139.172 ± .335 lbs.	143.072 ± .274 lbs.
	63.13 ± .15 kg.	64.89 ± .12 kg.
Standard deviation	17.265 ± .237 lbs.	17.273 ± .194 lbs.
	7.83 ± .11 kg.	7.83 ± .09 kg.
Coefficient of variation	12.406 ± .173	12.073 ± .137
Vital capacity:		
Mean	255.498 ± .685 cu.in	4354.6 ± 9.6 cc.
	4186.89 ± 11.22 cc.	
Standard deviation	35.240 ± .484 cu.in.	608.4 ± 6.8 cc.
	577.6 ± 7.9 cc.	
Coefficient of variation	15.63 ± .22	13.97 ± .15

31. Morant, G.M. Surveys of the Heights and Weights of Royal Air Force Personnel. VII. Heights and Weights of 137 Royal Air Force Apprentices Recorded on Fifteen Occasions. Flying Personnel Research Committee 711(f), R.A.F. Institute of Aviation Medicine, Farnborough, Hants, March 1952 (Armed Services Technical Information Agency No. AD-9758).

"This report deals with records of the heights and weights of 137 R.A.F. Apprentices (58th Entry) who were measured on fifteen occasions during a period of nearly three years, and with their medical histories, assessments of their physical fitness and final examination results. The following conclusions are reached:

(1) "No evidence was found of significant association between the assessments of health, physical fitness and ability, on the one hand, and age, on the other, or between any pair of the three criteria.

(2) "No evidence was found of seasonal fluctuations in the growth rates for height or weight.

(3) "There is a suggestion that the growth rate for height was accelerated appreciably in the second and third years of observation, and that the growth rate for weight was accelerated slightly at the same time.

(4) "All the Apprentices probably reached their maximum heights within a range extending from their 17th to 22nd years of age. For those presumed to have completed growth in height no correlation is found between maximum height and the age at which it was attained. For those who had not attained their maximum heights by age 18 years 4 months no correlation is found between height at 17 years 4 months and increase in height during the year 17 years 4 months to 18 years 4 months. Details regarding the last stage of skeletal growth appear to be peculiar to individuals.

(5) "There is no statistically significant association between any of the criteria examined regarding growth in height, on the one hand, and the criteria relating to health, physique and examination results, on the other.

(6) "Comparisons are made with a height-weight system based on records for earlier Entries (49th - 52nd) of R.A.F. Apprentices. Considered as a group, the 58th Entry was below the high standard of that series, but it was above the standards of most other series of British boys. Most of the Apprentices showed steady progressions in weight. Frequencies are given for normal and abnormal forms of height-weight curves, and distributions for changes in weight in different periods.

(7) "No evidence is found of any significant association between weight levels or changes in weight during particular intervals, on the one hand, and health, physique or examination results, on the other. As far as can be judged from the records, the boys with worst medical records did not show unusual changes in weight at times when they were ill, but the conclusion might have been different if weights had been recorded at shorter intervals than eight weeks. The average increase in weight for the series was peculiarly small during the interval proceeding the final examinations. Judging from this and other evidence, stress and change in living conditions appear to be the factors which have most influence on fluctuations in weight.

"For some of the subjects it is possible to estimate the age at which growth of the skeleton was completed--judging from cessation of growth in height--and to relate this age to the maximum height attained. Such estimates cannot be certain.for any of the subjects, however, because the age ranges covered...are not extensive. If, for a particular subject, the last heights recorded were steady, or almost steady, for more than one year (disregarding erratic falls or rises of 1/4 of an inch), then it may be presumed that maturity had been reached. This is not a sure criterion because there are a few cases...of heights being steady for more than one year, followed by a clear rise, but in the majority of cases it is probably reliable."

The report is 11 pages long; eight tables and six figures are included. There are no references. Selected data are presented with the annotation.

TABLE 31 - 1

Mean Heights and Weights (nude) for Different Age Groups Derived from all Readings Recorded for the 137 Apprentices on 15 Occasions

Age group (years)	No. of readings	Mean height (ins.)	Mean weight (lb)
15 2/3 - 16	39	67.04	126.5
16 - 16 1/3	111	67.69	132.2
16 1/3 - 16 2/3	157	67.87	133.9
16 2/3 - 17	189	68.50	135.8
17 - 17 1/3	246	68.56	137.6
17 1/3 - 17 2/3	269	68.74	138.2
17 2/3 - 18	237	68.99	139.0
18 - 18 1/3	211	69.33	140.8
18 1/3 - 18 2/3	193	69.34	140.4
18 2/3 - 19	124	69.34	140.7
19 - 19 1/3	80	69.36	142.6
19 1/3 - 19 2/3	57	69.57	141.1
19 2/3 - 20	31	69.46	143.9
20 - 20 1/3	10	69.47	143.3
20 1/3 - 20 2/3	2	70.50	160.3
20 2/3 - 21	1	68.00	128.0
Total	1957	-	-

TABLE 31 - 2

Distributions of Changes in the Weights of 437 Apprentices of the 58th Entry During Various Periods of Service

Differences in weight (lb)	Differences for intervals of: 8 Weeks (W2-W1)......... (W13-W12)*	22 weeks (W14-W13)	17 weeks (W15-W14)	135 weeks (W15 - W1)	Range of weights taken on 15 occasions (W1 - W15), without regard to sign+
-20/-15	2.5				
-15/-10	9.5			1.	
-10/-5	69	2		3.	
- 5/0	574.5	47.5	16.5	7.	
0/+5	736	49.5	65	26	2
+5/+10	124	6	25.5	32	34
+10/+15	8.5	-	4	27	47
+15/+20	2	-		13	22
+20/+25	1	0.5		11	15.5
+25/+30		0.5		4	5.5
+30/+35				2	2
+35/+40				2	2
No. of differences	1527	106	111	128	130
Mean difference	+0.54	+0.57	+3.27	+10.51	14.40

*Of the 12 intervals, 10 were of eight, 1 of seven, and 1 of nine, weeks.
+A range is not given if W15 was not recorded. Among the cases counted there are some for which the numbers of repeated weights are rather less than 15.

32. Newman, Russell W. Changes in Body Dimensions During Basic Training in Relation to Clothing Sizes. Environmental Protection Division, Report No. 176, Quartermaster Research and Development Command, Natick, Massachusetts, August 1951.

"Purpose. This study was initiated to investigate body dimension changes which take place in young men subjected to a rigorous military environment for the first time. These changes, as defined in terms of nude body measurements, have been analyzed in relation to clothing requirements for these men during the course of their basic training.

"Summary. Five girth dimensions, waist, seat, chest, shoulder, and neck, showed the greatest amount of change and were analyzed in detail. It has been shown that a sizable percentage of men change their girth dimensions sufficiently during basic training to require alterations on garments sized to their pre-training girths. These changes were shown to be largely assignable to men who were either small or large, and each group showed a definite trend in opposite directions. The small men tended to gain and the large men tended to lose. Fortunately, this allowed for a statistical analysis which differentiated and predicted girth changes with a reasonable degree of accuracy.

"Conclusions. The most logical approach to the problem of sizing men entering the Army is to predict girth changes by means of data collected on men undergoing basic training and allow for these changes in the initial fitting. The limitations of such data were discussed, but it was evident that for all their limitations they represented an anthropometric estimate that should be preferable to not taking possible changes into account.

"Recommendations. That the predictions of girth changes presented here be considered for use by personnel charged with initial issue of clothing. That additional data be gathered to strengthen the predictions.

TABLE 32 - 1

Change in Waist Circumference of Men (1950 Fort Dix Series) During Basic Training

	Inches	1st Seven Weeks	2nd Seven Weeks	Total Basic Training
Gain	3-4			1.57%
	2-3	5.12%	1.57%	9.45%
	1-2	20.47%	12.20%	18.90%
No Change		55.51%	73.62%	46.85%
Loss	1-2	11.81%	9.06%	12.60%
	2-3	4.33%	3.54%	5.51%
	3-4	2.76%		2.76%
	4-5			1.57%
	5-6			0.79%

TABLE 32 - 2

Regression Equations in Inches for Estimating Girth Changes

Waist Measurement

$$\begin{aligned}
\text{Waist Girth} &= (-.375 \text{ Waist} + 11.859) \pm 1.144 \\
\text{Seat } '' &= (-.225 \text{ Waist} + 7.414) \pm .925 \\
\text{Chest } '' &= (-.169 \text{ Waist} + 4.850) \pm .909 \\
\text{Shoulder } '' &= (-.166 \text{ Waist} + 4.924) \pm .872 \\
\text{Neck } '' &= (-.051 \text{ Waist} + 1.400) \pm .487
\end{aligned}$$

Weight

$$\begin{aligned}
\text{Waist Girth} &= (-.044 \text{ Weight} + 7.016) \pm 1.310 \\
\text{Seat } '' &= (-.028 \text{ Weight} + 4.761) \pm .983 \\
\text{Chest } '' &= (-.022 \text{ Weight} + 3.011) \pm .931 \\
\text{Shoulder } '' &= (-.021 \text{ Weight} + 3.021) \pm .892 \\
\text{Neck } '' &= (-.006 \text{ Weight} + .744) \pm .496
\end{aligned}$$

Height/ $\sqrt[3]{\text{Weight}}$

$$\begin{aligned}
\text{Waist Girth} &= (1.751 \text{ Ht}/\sqrt[3]{\text{Wt}} - 22.217) \pm 1.383 \\
\text{Seat } '' &= (1.023 \text{ Ht}/\sqrt[3]{\text{Wt}} - 12.681) \pm 1.044 \\
\text{Chest } '' &= (\ .843 \text{ Ht}/\sqrt[3]{\text{Wt}} - 11.193) \pm .961 \\
\text{Shoulder } '' &= (\ .897 \text{ Ht}/\sqrt[3]{\text{Wt}} - 11.712) \pm .907 \\
\text{Neck } '' &= (\ .254 \text{ Ht}/\sqrt[3]{\text{Wt}} - 3.436) \pm .497
\end{aligned}$$

Method of calculating predicted girth changes: If the waist (or weight, or $\frac{\text{height}}{\sqrt[3]{\text{weight}}}$) measurement is known (40 inches, for example) then the change in any of the girth measurements can be estimated by inserting this known value in the appropriate regression equation, for example:

$$\begin{aligned}
\text{waist girth (change)} &= (-.375 \times 40.00 + 11.859) \pm 1.144 \\
&= (-15.000 + 11.859) \pm 1.144 \\
&= -3.141 \pm 1.144
\end{aligned}$$

The waist girth change predicted for a 40-inch waist is 3.141 inches smaller (since the sign is negative). The reliability of this prediction is indicated by its standard error (± 1.144).

The report contains 25 pages and includes 18 tables; Tables 32-1 and 32-2 are included here as being particularly relevant. Three bibliographic references are provided in footnotes.

33. O'Brien, Ruth and William C. Shelton. Women's Measurements for Garment and Pattern Construction. Miscellaneous Publication Number 454, United States Department of Agriculture in cooperation with the Work Projects Administration, Textiles and Clothing Division, Bureau of Home Economics, December 1941.

Purpose: "This research project was undertaken in order to provide measurements which could be used, for improving the fit of women's garments and patterns. No scientific study of body measurements used in the construction of women's clothing has ever been reported. The measurements used have grown up in the industry, apparently chiefly by trial and error, based on measurements taken on a few women by various inaccurate procedures. As a result, there are no standards for garment sizes, and retailers and consumers are subjected to unnecessary expense and harassed by the difficulties involved in obtaining properly fitting clothing."

Subjects: The number of women whose measurements are included in the analysis were white residents and visitors in Arkansas (N = 1480), California (N = 2119), Illinois (N = 889), Maryland (N = 522), New Jersey (N = 2119), North Carolina (N = 588), Pennsylvania (N = 1083), and the District of Columbia (N = 1242); grand total, N = 10,042. "They were 18 years of age and older and were both native and foreign-born. Most of them lived in urban areas.

"Measuring centers were set up in the cities and towns, and invitations issued to women through their organizations. Colleges, Work Projects Administration sewing rooms, social welfare centers, and other women's organizations were invited to participate. Some measuring was also done in private homes."

The sample was not random, but was systematically adjusted so as to correspond approximately in age distribution to the Census of 1930. There is correlational evidence that this controlling of the age variable results in controlling all other major anthropometric variables as well. The sample is therefore presumed to be nationally representative.

Procedures: "Identical calibrated measuring instruments were used by all units. The measuring costume, which was also standard throughout the project, consisted of knit cotton shorts cut high on the hips and bandeaux which fit snugly but not tightly. All garments were laundered after each wearing."

The kits of instruments and small supplies provided for each measuring squad contained:

2 anthropometers	1 package of pins
1 protractor	2 neck chains
1 sliding caliper	1 steel guide rod
1 2-meter steel tape	1 spool of twine
4 skin pencils	1 carpenters chalk
1 pocket knife or package of razor blades	1 manual of measurements

"Each squad was supplied with one portable leveling platform, one portable weighing scale, and the cold cream and cotton used to remove the skin pencil marks placed on the women as landmarks for measuring."

"The measurements and the procedures followed in taking each measurement were determined after conferences with leading pattern and garment manufacturers and retail distributors of women's clothing. The schedule included weight and 58 measurements. Of these, 54 were taken with the subject wearing only the measuring costume.

If she customarily wore a foundation garment, she was then asked to put it on, and 4 of the trunk-girth measurements were retaken. The complete list of measurements included those used in constructing all garments except shoes, hats, and gloves." Weight was measured in pounds, shoulder slope was measured in degrees; all other measurements were metric and were recorded to the nearest millimeter. All of the measurers were trained to insure comparability of results.

Conclusions: Practical and theoretical considerations alike agree in suggesting the use of <u>stature</u> (total height) and <u>weight</u>, certain girth measurements) as being the two most usable predictors of the other dimensions of a woman's body. This is due to the fact that "while the vertical measurements and, to an even greater degree, the horizontal measurements are rather highly correlated among themselves, many of the correlations of vertical with horizontal measurements are very small and some are actually negative."

Figures are presented describing the stature-weight system and also the alternative stature-girth systems.

This report is 73 pages long and includes 52 tables and 13 figures, as well as 14 pages of photographs illustrating the proper taking of the measurements. Means and standard deviations are given, but no percentiles. There is no bibliography but seven references are given in footnotes throughout the report. Selected data are presented with this annotation.

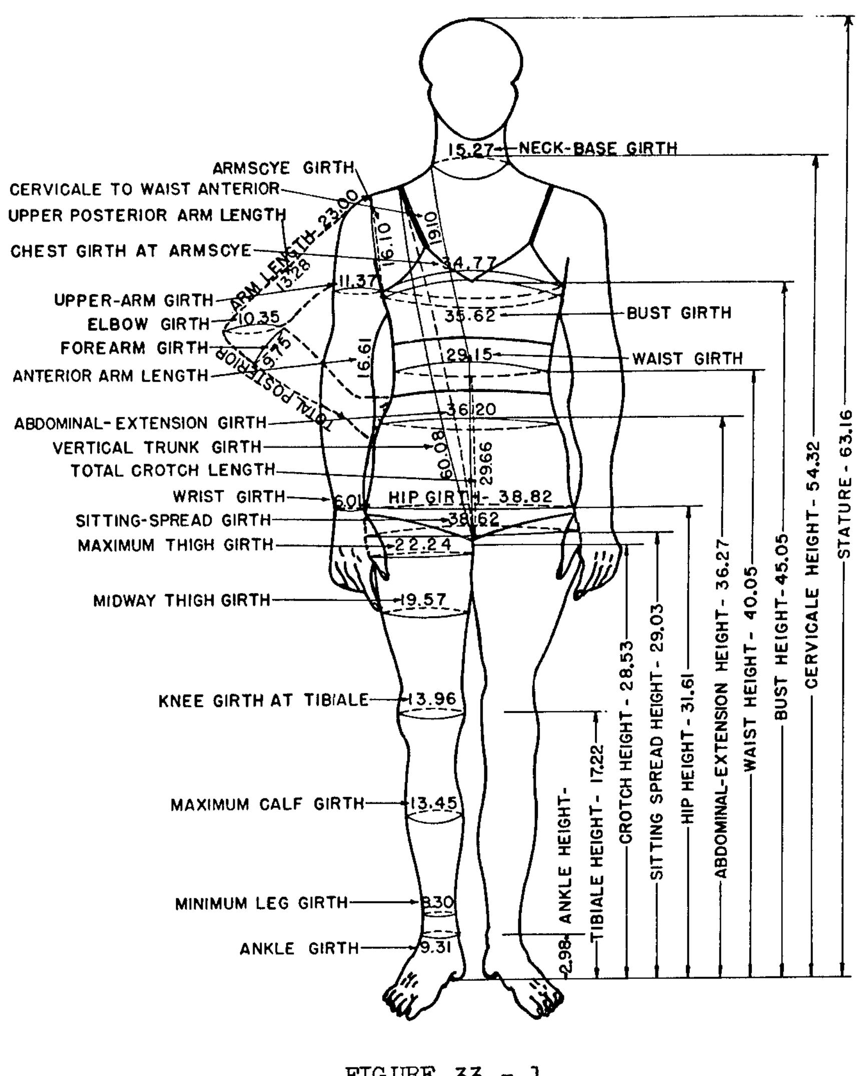


FIGURE 33 - 1
The Average (Arithmetic Mean) Woman, Showing 34 Measurements (in Inches).

TABLE 33 - 1

Means, Medians, Modes, Standard Deviations, and Coefficients of Variation of 59 Measurements of 10,042 Women

Item number and measurement	Mean	Median	Mode	Standard deviation	Coefficient of variation
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Percent*
1. Weight	133.48	128.72	120.00	25.98	19.5
Vertical measurements:	*Inches*	*Inches*	*Inches*	*Inches*	
2. Stature	63.16	63.19	63.23	2.48	3.9
3. Cervicale height	54.32	54.34	54.75	2.30	4.2
4. Bust height	45.05	45.09	44.83	2.31	5.1
5. Waist height	40.05	40.04	39.96	1.95	4.9
6. Abdominal-extension height	36.27	36.30	36.45	1.94	5.3
7. Hip height	31.61	31.61	31.89	1.78	5.6
8. Sitting-spread height	29.03	29.05	28.90	1.79	6.2
9. Crotch height	28.53	28.52	28.43	1.74	6.1
10. Tibiale height	17.22	17.23	17.29	1.07	6.2
11. Ankle height	2.98	2.97	2.98	.28	9.4
12. Total posterior arm length	23.00	23.00	23.20	1.17	5.1
13. Upper posterior arm length	13.28	13.27	13.27	.76	5.8
14. Anterior arm length	16.61	16.61	16.56	1.13	6.8
15. Sitting height	24.60	24.61	24.62	1.19	4.9
16. Vertical trunk girth	60.08	59.73	58.82	3.32	5.5
17. Cervicale to waist anterior	19.10	19.07	18.88	1.10	5.7
18. Anterior waist length	12.89	12.87	12.91	.89	6.9
19. Shoulder to waist	15.60	15.56	15.50	1.04	6.6
20. Neck to bust	11.03	10.85	10.58	1.50	13.6
21. Posterior waist length	14.97	14.93	14.86	.93	6.2
22. Scye depth	7.77	7.71	7.60	.84	10.8
23. Trunk line	7.64	7.63	7.57	.91	12.0
24. Arm length, shoulder to scye	5.48	5.44	5.40	.68	12.4
25. Waist to hip	9.03	9.01	9.04	.94	10.4
26. Total crotch length	29.66	29.37	28.63	2.47	8.3
27. Anterior crotch length	14.52	14.36	14.12	1.53	10.6
Horizontal measurements:					
28. Chest girth at armscye	34.77	34.17	33.30	3.20	9.2
29. Bust girth	35.62	34.79	33.69	3.87	10.9
30. Waist girth	29.15	27.93	25.86	4.45	15.3
31. Abdominal-extension girth	36.20	35.25	33.41	4.71	13.0
Horizontal measurements—Con.	*Inches*	*Inches*	*Inches*	*Inches*	*Percent*
32. Hip girth	38.82	38.35	37.81	3.34	8.6
33. Sitting-spread girth	38.62	38.04	37.05	3.91	10.1
34. Maximum thigh girth	22.24	22.05	21.89	2.25	10.1
35. Midway thigh girth	19.57	19.38	18.82	2.03	10.4
36. Bent knee girth	14.29	14.14	13.88	1.38	9.7
37. Knee girth at tibiale	13.96	13.81	13.61	1.27	9.1
38. Maximum calf girth	13.45	13.34	13.02	1.20	9.0
39. Minimum leg girth	8.30	8.25	8.22	.69	8.3
40. Ankle girth	9.31	9.25	9.16	.67	7.2
41. Neck-base girth	15.27	15.20	15.17	.93	6.1
42. Armscye girth	16.10	15.89	15.57	1.55	9.6
43. Upper-arm girth	11.37	11.14	10.54	1.51	13.2
44. Elbow girth	10.35	10.25	10.13	.88	8.5
45. Forearm girth	9.75	9.65	9.50	.84	8.7
46. Wrist girth	6.01	6.00	5.95	.38	6.4
47. Shoulder length	4.64	4.62	4.63	.49	10.6
48. Anterior chest width	12.47	12.42	12.30	.90	7.2
49. Highest bust-level width	7.36	7.32	7.25	.81	11.0
50. Posterior chest width	13.39	13.31	13.26	1.22	9.1
51. Anterior bust arc	20.08	19.61	19.11	2.67	13.3
52. Anterior waist arc	16.52	15.79	14.71	2.88	17.4
53. Abdominal-extension arc	19.67	19.11	18.35	2.70	13.7
54. Posterior hip arc	19.17	18.96	18.48	1.93	10.1
55. Bust girth over foundation garment [1]	35.65	34.81	33.69	3.91	11.0
56. Waist girth over foundation garment [1]	29.19	27.96	25.88	4.46	15.3
57. Abdominal-extension girth over foundation garment [1]	36.14	35.22	33.38	4.64	12.8
58. Hip girth over foundation garment [1]	38.80	38.31	37.81	3.36	8.7
Angle:	*Degrees*	*Degrees*	*Degrees*	*Degrees*	
59. Shoulder slope	23.08	23.22	24.11	4.13	17.9

TABLE 33 - 2

Correlations Among 59 Measurements of 4,128 Women

Measurement	Stature	Cervicale height	Bust height	Waist height	Abdominal-extension height	Hip height	Sitting-spread height	Crotch height	Tibiale height	Ankle height	Total posterior arm length	Upper posterior arm length	Anterior arm length	Sitting height	Vertical trunk girth	Cervicale to waist anterior	Anterior waist length	Shoulder to waist	Neck to bust
Weight	.2264	.2878	.0420	.2568	.1063	.1210	.1115	.0544	.1427	.0779	.2892	.2454	.0732	.3019	.8795	.5376	.3822	.4773	.5546
Vertical measurements:																			
Stature		[1].9493	[1].8880	[1].9092	[1].8350	[1].8262	[1].8043	[1].8480	[1].7399	[1].3192	.7484	.6803	.6636	.6710	.3568	.3910	.3626	.3577	.0376
Cervicale height			[1].8722	[1].9178	[1].8412	[1].8322	[1].8120	[1].8487	[1].7495	[1].3178	.7648	.6082	.6584	[1].6938	.4124	.3876	.3546	.3611	.0791
Bust height				[1].8676	[1].8280	[1].8161	[1].7975	[1].8526	[1].7208	[1].3009	.6867	.6241	.6516	.5790	.1676	.2587	.2633	.2221	−.2047
Waist height					[1].8652	[1].8614	[1].8452	[1].8746	[1].7676	[1].3043	.7751	.6924	.6653	.5701	.3313	.2096	.1481	.2013	.0521
Abdominal-extension height						[1].8235	[1].8121	[1].8468	[1].7265	[1].2931	.7198	.6426	.6492	.4799	.1704	.1989	.1653	.1729	−.0431
Hip height							[1].8375	[1].8628	[1].7220	[1].2875	.7360	.6599	.6547	.4604	.1696	.1922	.1692	.1845	−.0297
Sitting-spread height								[1].8489	[1].7178	[1].2764	.7152	.6398	.6389	.4262	.1594	.1896	.1555	.1656	−.0418
Crotch height									[1].7604	[1].2705	.7380	.6598	.6787	.4418	.0942	.1948	.1732	.1879	−.0671
Tibiale height										[1].2607	.6415	.5687	.5798	.4311	.1865	.2084	.1852	.1962	.0173
Ankle height											.2357	.2275	.2121	.2464	.1245	.1233	.1087	.1023	−.0060
Total posterior arm length												[1].8821	.7431	.4362	.3010	.2774	.2299	.2504	.1039
Upper posterior arm length													.6589	.4169	.2743	.2602	.2231	.2261	.0921
Anterior arm length														.3449	.0927	.1928	.1893	.1594	−.0360
Sitting height															.4941	.4201	.4029	.4011	.1142
Vertical trunk girth																.6023	.4825	.5561	.5158
Cervicale to waist anterior																	.8240	.7503	.3278
Anterior waist length																		.6960	.2392
Shoulder to waist																			.3923

Measurement	Posterior waist length	Scye depth	Trunk line	Arm length, shoulder to scye	Waist to hip	Total crotch length	Anterior crotch length	Chest girth at armscye	Bust girth	Waist girth	Abdominal-extension girth	Hip girth	Sitting-spread girth	Maximum thigh girth	Midway thigh girth	Bent knee girth	Knee girth at tibiale	Maximum calf girth	Minimum leg girth
Weight	.3387	.4528	−.0842	.3593	.3360	.8168	.7215	.8874	.8926	.8755	.8985	.9174	.9063	.8779	.8295	.7745	.7685	.7628	.6030
Vertical measurements:																			
Stature	.4555	.1709	.2902	.2222	.3151	.1951	.1704	.0737	.0206	−.0497	.0124	.1257	.0895	.1011	.0771	.2300	.1825	.1625	.1556
Cervicale height	.5235	.2560	.2624	.2516	.3231	.2466	.2066	.1318	.0803	.0269	.0835	.1614	.1485	.1537	.1173	.2727	.2307	.1900	.1809
Bust height	.3307	.0322	.3034	.1122	.2413	.0342	.0233	−.0762	−.1353	−.2185	−.1681	−.0371	−.0753	−.0371	−.0535	.0084	.0508	.0345	.0462
Waist height	.2758	.1805	.1001	.2458	.3861	.2916	.2468	.1126	.0695	.0011	.0747	.1642	.1393	.1351	.0972	.2512	.2026	.1665	.1421
Abdominal-extension height	.2998	.1150	.1811	.1347	.2275	.0701	.0539	−.0078	−.0516	−.1153	−.1224	.0230	−.0118	.0061	−.0247	.1394	.0943	.0655	0800
Hip height	.2931	.1184	.1803	.1664	−.0309	.0658	.0580	−.0031	−.0428	−.0529	−.0469	.0287	.0183	.0132	.0080	.1197	.1304	.0529	.0710
Sitting-spread height	.2868	.1308	.1690	.1501	.1618	.0586	.0438	.0116	−.0305	−.0817	−.0411	.0429	.0378	−.0024	−.0267	.1373	.0777	.0440	.0601
Crotch height	.2827	.0770	.1778	.1251	.1623	−.0233	−.0117	−.0383	−.0851	−.1539	−.1101	−.0454	−.0638	−.0478	−.0733	.0955	.0399	.0132	.0169
Tibiale height	.2996	.1368	.1578	.1425	.2243	.0909	.0951	.0401	.0063	−.0417	−.0030	.0629	.0313	.0479	.0475	.1933	.1999	.0951	.0943
Ankle height	.1411	.0836	.0940	.1040	.0926	.0563	.0694	.0358	.0067	−.0352	−.0225	.0483	.0191	.0369	.0397	.0595	.0555	.0764	.0688
Total posterior arm length	.3446	.2618	.1120	.3250	.2219	.1958	.1763	.1876	.1394	.0865	.1324	.1949	.1671	.1580	.1098	.2525	.2159	.1809	.1632
Upper posterior arm length	.3503	.2647	.1114	.3473	.2020	.1712	.1597	.1506	.1078	.0610	.1062	.1644	.1407	.1349	.0763	.2037	.1743	.1442	.1455
Anterior arm length	.2572	.0835	.2358	.0781	.1370	.0104	.0229	−.0170	−.0654	−.1164	−.0703	.0126	−.0210	−.0155	−.0301	.0908	.0439	.0408	.0382
Sitting height	.5545	.2785	.2770	.2476	.3153	.3387	.2846	.1766	.1358	.0805	.1382	.2399	.2132	.2226	.1930	.2519	.2473	.2248	.2061
Vertical trunk girth	.4714	.4494	.0788	.4450	.3888	.8210	.7244	.7798	.7779	.7694	.7863	.7931	.7798	.7343	.6700	.6575	.6598	.6170	.5216
Cervicale to waist anterior	.5235	.2103	.3441	.2299	.1168	.2783	.2479	.4995	.4776	.4221	.4007	.4329	.3998	.4146	.3909	.3908	.3815	.3757	.3278
Anterior waist length	.5564	.1947	.4147	.1472	.0401	.1303	.1252	.3360	.3175	.2909	.2674	.2951	.2686	.2812	.2659	.2823	.2840	.2639	.2415
Shoulder to waist	.4817	.1524	.3474	.2639	.1192	.2398	.2045	.4235	.4413	.3378	.3480	.3822	.3538	.3890	.3548	.3465	.3453	.3358	.2712
Neck to bust	.1881	.3100	−.0948	.2914	.1776	.4735	.4245	.5275	.5656	.5531	.5612	.4912	.4972	.4531	.4037	.3750	.3867	.3627	.2791
Posterior waist length		.4540	.3973	.1895	.0656	.1353	.1430	.2463	.2191	.2484	.2350	.2674	.2420	.2330	.1898	.2681	.2725	.2272	.2429
Scye depth			−.1146	.3371	.1775	.3959	.3690	.4122	.3958	.4464	.4592	.4101	.4196	.3615	.2982	.3344	.3365	.2939	.2697
Trunk line				−.0944	−.1371	−.2109	−.1833	−.1587	−.1629	−.1749	−.1973	−.1083	−.1522	−.1061	−.0867	−.0582	−.0677	−.0476	−.0073
Arm length, shoulder to scye					.2386	.4164	.3772	.4112	.3887	.3627	.3961	.3632	.3788	.3394	.2709	.2698	.2772	.2654	.1998
Waist to hip						.4794	.4071	.2524	.2442	.2054	.2779	.3365	.3034	.3006	.2187	.3156	.2977	.2711	.2319
Total crotch length							[1].8390	.7215	.7236	.7209	.7838	.7871	.7819	.7249	.6698	.6220	.6216	.5853	.4620
Anterior crotch length								.6548	.6586	.6608	.7080	.6676	.6767	.6085	.5654	.5357	.5363	.5068	.3760
Horizontal measurements:																			
Chest girth at armscye									.9328	.8802	.8517	.7875	.7836	.7438	.6910	.6226	.6189	.6094	.4617
Bust girth										.9050	.8727	.7926	.7917	.7433	.6912	.6165	.6159	.6106	.4569
Waist girth											.9256	.8006	.8083	.7201	.6642	.6165	.6252	.5776	.4639
Abdominal-extension girth												.8633	.8721	.7861	.7234	.6540	.6638	.6068	.4729
Hip girth													.9407	.9120	.8426	.7477	.7494	.7285	.5769
Sitting-spread girth														.8995	.8386	.7412	.7421	.7218	.5570
Maximum thigh girth															.9096	.7358	.7486	.7513	.5662
Midway thigh girth																.7402	.7531	.7720	.5819
Bent knee girth																	.8528	.7667	.6650
Knee girth at tibiale																		.7540	.6627
Maximum calf girth																			.7232

TABLE 33 - 2 (Continued)

Measurement	Ankle girth	Neck-base girth	Armscye girth	Upper-arm girth	Elbow girth	Forearm girth	Wrist girth	Shoulder length	Anterior chest width	Highest bust-level width	Posterior chest width	Anterior bust arc	Anterior waist arc	Abdominal-extension arc	Posterior hip arc	Bust girth over foundation garment	Waist girth over foundation garment	Abdominal-extension girth over foundation garment	Hip girth over foundation garment	Angle of shoulder slope
Weight	.5464	.6803	.8249	.8742	.7453	.8254	.6524	.2790	.6102	.5470	.6447	.8253	.8249	.8175	.7726	.8890	.8715	.8903	.9174	−.0445
Vertical measurements:																				
Stature	.2730	.1919	.1203	−.0269	.1643	.1401	.2492	.2110	.2259	.0979	.1038	−.0028	−.0670	.0085	.0939	.0183	−.0530	.0180	.1185	.0454
Cervicale height	.2996	.2159	.1793	.0357	.2029	.1904	.2916	.2393	.2525	.1215	.1133	.0518	.0106	.0827	.1334	.0756	.0238	.0870	.1764	.0121
Bust height	.1691	.0578	−.0172	−.1843	.0328	−.0035	.1087	.0991	.1086	−.0175	−.0202	−.1808	−.2189	−.1616	−.0341	−.1377	−.2239	−.1022	−.0144	.0181
Waist height	.2610	.1936	.1441	.0160	.1816	.1604	.2470	.2256	.2279	.1058	.1265	.0413	−.0173	.0731	.1161	.0082	−.0022	.0777	.1591	.0291
Abdominal-extension height	.2038	.1095	.0245	−.1104	.0779	.0424	.1572	.1785	.1406	.0540	.0596	−.0810	−.1261	−.0974	.0126	−.0533	−.1183	−.1203	.0181	.0366
Hip height	.1810	.1091	.0362	−.1059	.0690	.0423	.1380	.1589	.1399	.0646	.0572	−.0760	−.1100	−.0108	−.0004	−.0159	−.1061	−.0431	.0253	.0131
Sitting-spread height	.1984	.0962	.0406	−.1024	.0798	.0402	.1587	.1565	.1404	.0266	.0428	−.0553	−.0988	−.0170	.0311	−.0324	−.0859	−.0385	.0371	.0211
Crotch height	.1666	.0722	−.0141	−.1567	.0324	−.0021	.1212	.1504	.1134	.0154	.0176	−.1068	−.1630	−.1116	−.0167	−.0874	−.1580	−.1077	−.0501	.0282
Tibiale height	.2104	.1146	.0650	−.0468	.1054	.0600	.1836	.2166	.1708	.0378	.0676	−.0182	−.0587	−.0122	.0500	.0031	−.0151	−.0010	.0582	.0221
Ankle height	.0567	.0756	.0363	−.0148	.0616	.0786	.1241	.0863	.1280	.0017	.0656	−.0012	−.0115	−.0191	.0367	.0058	−.0376	−.0192	.0430	−.0131
Total posterior arm length	.2933	.2225	.2422	.0764	.2410	.2136	.3224	.1755	.2709	.1770	.1784	.1022	.0690	.1168	.1594	.1371	.0824	.1303	.1900	−.0118
Upper posterior arm length	.2549	.1703	.2325	.0533	.2107	.1842	.0871	.1155	.2320	.1395	.1302	.0729	.0416	.0870	.1455	.1073	.0581	.1095	.1610	−.0093
Anterior arm length	.1663	.0720	−.0262	−.1234	.0250	.0044	.1487	.2059	.1358	.0507	.0511	−.0855	−.1222	−.0675	.0016	−.0085	−.1108	−.0961	.0098	.0287
Sitting height	.3524	.2005	.2140	.1324	.2303	.2426	.2710	.1843	.2220	.1206	.1654	.1079	.0751	.1437	.1807	.1311	.0787	.1104	.2390	.0561
Vertical trunk girth	.4984	.6124	.7579	.7446	.6486	.7143	.6190	.2455	.5681	.4882	.5482	.7179	.7312	.7617	.6531	.7749	.7690	.7872	.7951	−.0524
Cervicale to waist anterior	.3730	.4819	.4861	.4345	.4157	.4417	.4271	.1597	.4375	.3658	.3443	.4752	.4168	.3818	.3702	.4752	.4160	.4011	.4301	−.0137
Anterior waist length	.2811	.2549	.3423	.2800	.2800	.2966	.3133	.1088	.3402	.2811	.1923	.3298	.3034	.2636	.2541	.3146	.2861	.2680	.2910	−.0072
Shoulder to waist	.2986	.3778	.4355	.3803	.3470	.3814	.3309	.1398	.4131	.2884	.2019	.4780	.3356	.3295	.3146	.4361	.3333	.3196	.3804	−.0026
Neck to bust	.2627	.3780	.5144	.5271	.3922	.4426	.3555	.2115	.3813	.3508	.3411	.5942	.5282	.5139	.3438	.5037	.5519	.5570	.4953	.0002
Posterior waist length	.2888	.2080	.2881	.1992	.2465	.2479	.3205	.1915	.2060	.1676	.2352	.1669	.2277	.2276	.2226	.2150	.2461	.2364	.2656	.0506
Scye depth	.2904	.2101	.4398	.4006	.3422	.3716	.3830	.2269	.2930	.2277	.3193	.3546	.4248	.4334	.3158	.3934	.4476	.4515	.4111	.0932
Trunk line	.0484	−.0372	−.1480	−.1807	−.0970	−.1181	−.0079	−.0010	−.0057	−.0234	−.0933	−.1664	−.1839	−.1953	−.0714	−.1655	−.1788	−.1928	−.1120	−.1110
Arm length, shoulder to scye	.2138	.2863	.5211	.3487	.3456	.3837	.3025	.0126	.2481	.1932	.2875	.3560	.3356	.3030	.3028	.3863	.3591	.3952	.3646	−.0808
Waist to hip	.2096	.1946	.2658	.2591	.2684	.2721	.2415	.1569	.2132	.0926	.1582	.2539	.1956	.2641	.2851	.2442	.2059	.2778	.3331	−.0327
Total crotch length	.4141	.5256	.6791	.7309	.6071	.6737	.5236	.2319	.4770	.4279	.5093	.6710	.6870	.7603	.6402	.7231	.7198	.7810	.7879	−.0105
Anterior crotch length	.3375	.4686	.6024	.6391	.5321	.5781	.4567	.2008	.4305	.3967	.4707	.6095	.6276	.6896	.5418	.6578	.6586	.7061	.6089	−.0152
Horizontal measurements:																				
Chest girth at armscye	.4352	.6679	.8073	.8625	.6970	.7712	.5891	.2540	[1].6201	.5624	[1].6995	.8460	.8349	.8131	.6522	.9297	.8738	.8102	.7901	−.0078
Bust girth	.4219	.6432	.8034	.8604	.6764	.7514	.5664	.2239	.5798	.5617	.6591	[1].9148	.8623	.8397	.6503	[1].9938	.8985	.8681	.7906	−.0818
Waist girth	.4326	.6199	.7887	.8487	.6527	.7114	.5796	.2203	.5356	.5444	.6255	.8338	[1].9440	.8964	.6484	.9026	[1].9033	.9203	.8087	−.0641
Abdominal-extension girth	.4357	.5879	.7869	.8503	.6534	.7179	.5681	.2220	.5246	.5163	.5912	.8176	.8871	[1].9304	.7047	.8710	.9217	[1].9942	.8678	−.0528
Hip girth	.4960	.5661	.7409	.8216	.6783	.7562	.5684	.2294	.5203	.4680	.5616	.7320	.7434	.7889	[1].8609	.7901	.7901	.8005	[1].9924	−.0432
Sitting-spread girth	.4706	.5566	.7398	.8123	.6554	.7356	.5433	.2037	.4995	.4635	.5392	.7268	.7015	.8079	.8095	.7897	.8081	.8686	.9370	−.0399
Maximum thigh girth	.4546	.5275	.7066	.8068	.6568	.7548	.5106	.1963	.4878	.4361	.5133	.6972	.6696	.7065	.8151	.7421	.7182	.7846	.9018	−.0212
Midway thigh girth	.4615	.5094	.6435	.7587	.6254	.7277	.5015	.2080	.4680	.4057	.4799	.6562	.6264	.6539	.7431	.6894	.6621	.7220	.8316	−.0241
Bent knee girth	.5813	.4814	.6041	.6511	.6112	.6664	.5920	.2154	.4458	.3837	.4190	.5783	.5713	.6006	.6479	.6157	.6160	.6527	.7416	−.0108
Knee girth at tibiale	.5563	.4828	.6102	.6622	.6117	.6729	.5791	.2001	.4407	.3724	.4175	.5807	.5812	.6074	.6538	.6166	.6247	.6632	.7445	−.0135
Maximum calf girth	.5620	.4776	.5671	.6372	.5935	.6885	.5368	.2086	.4276	.3578	.4424	.5631	.5223	.5516	.6453	.6068	.5755	.6076	.7236	−.0226
Minimum leg girth	.6924	.3844	.4469	.4785	.5068	.5662	.6009	.1785	.3316	.2831	.3395	.1127	.4164	.4339	.5122	.4554	.4630	.4761	.5735	−.0200
Ankle girth		.3704	.4467	.4033	.4857	.4933	.6027	.1815	.3322	.3277	.3270	.3865	.3942	.4140	.4242	.4205	.4285	.4377	.4930	−.0031
Neck-base girth			.6005	.6118	.5518	.6038	.4856	.1933	.5145	.4600	.5300	.5769	.5824	.5671	.4678	.6425	.6122	.5900	.5692	.0000
Armscye girth				.8271	.6971	.7476	.5988	.1467	.5381	.4951	.5320	.7564	.7589	.7497	.6116	.7993	.7856	.7842	.7402	−.0005
Upper-arm girth					.7228	.8142	.5776	.2155	.5433	.5085	.5810	.8038	.8077	.8026	.6850	.8588	.8446	.8404	.8210	−.0251
Elbow girth						.8369	.6159	.1956	.4836	.4212	.4961	.6203	.6200	.6209	.5684	.6739	.6488	.6505	.6758	−.0033
Forearm girth							.6405	.2123	.5219	[illegible]	.5462	.6904	.6732	.6769	.6305	.7488	.7068	.7170	.7511	−.0008
Wrist girth								.2575	.4520	.4005	.4350	.5105	.5366	.5401	.4744	.5617	.5769	.5072	.5675	−.0205
Shoulder length									.3788	.1421	.3009	.1821	.1910	.2204	.1558	.2187	.2220	.2240	.2285	.1534
Anterior chest width										.4783	.2669	.5879	.5151	.4089	.4251	.5753	.5310	.5240	.5205	−.0279
Highest bust-level width											.3596	.5561	.5380	.5132	.3746	.5610	.5400	.5132	.4683	−.0232
Posterior chest width												.5085	.5675	.5612	.4704	.6566	.6207	.5920	.5646	−.0371
Anterior bust arc													.8432	.8163	.5626	.9108	.8297	.8124	.7357	−.0713
Anterior waist arc														.9237	.5377	.8595	.9386	.8808	.7533	−.0544
Abdominal-extension arc															.5312	.8375	.8950	.9250	.7983	−.0516
Posterior hip arc																.6445	.6479	.7034	.8517	−.0239
Bust girth over foundation garment																	.8050	.8650	.7939	−.0652
Waist girth over foundation garment																		.9204	.8069	−.0607
Abdominal-extension girth over foundation garment																			.8660	−.0518
Hip girth over foundation garment																				−.0472

54. Quartermaster Corps, U.S. Army. Survey of Body Size of Army Personnel, Male and Female (1946): Body Dimensions of Army Females. Project No. E-59-46, Environmental Protection Division, Quartermaster Research and Development Center, Natick, Massachusetts.

Body size data for 52 measurements of approximately 8500 members of the Women's Army Corps and Army Nurse Corps are provided for use by designers of women's clothing and other personal equipment.

The age range of the subjects was from 18 to 54 years, with 88.72% falling in the 18-34 year range.

The statistics reported for each measurement are: Number of subjects, range, mean, standard deviation and selected percentiles from the first to ninety-ninth.

Table 34-1 presents essential measurement data from this study.

Annotator's note: This "annotation" is based upon unpublished material received by letter communication from the originating agency. It refers to no specific report, but to data obtained during the survey indicated.

See also: Munro, Ella H. Preparation of Anthropometric Nomographs. Environmental Protection Division, Report No. 184, Quartermaster Research and Development Command, Natick, Massachusetts, February 1952.

Randall, Francis E. and Ella H. Munro. Reference Anthropometry of Army Women. Environmental Protection Division, Report No. 149, Quartermaster Research and Development Center, Natick, Massachusetts, 31 March 1949.

Randall, Francis E. and Ella H. Munro. Anthropometric Nomograph of Army Women. Environmental Protection Division Report No. 148, Quartermaster Research and Development Center, Natick, Massachusetts, 10 February 1949.

35. Quartermaster Corps, U.S. Army. Survey of Body Size of Army Personnel, Male and Female (1946): Body Dimensions of Army Males. Project No. E-59-46, Environmental Protection Division, Quartermaster Research and Development Center, Natick, Massachusetts.

Body size data for 65 measurements of 25,000 Army males are provided for use by designers of clothing and equipment intended for men in the Army. These data were derived from an anthropometric survey conducted by the Quartermaster Corps in 1946. Approximately 85,000 U.S. Army white males were measured in the survey.

"The men measured in this survey had been in military service for varying lengths of time. They represented a sample of men who were not only segregated by the process of military selection, but also exposed to a military environment. This group is thus not necessarily representative of civilian groups of comparable size and age distribution. Men entering the service and the potential pool of manpower from which the services draw may differ somewhat in the distribution of body sizes and bodily proportions. The men reported here were all measured as they were processed through separation centers at the close of World War II. They were civilian soldiers returning to civilian life and may not accurately reflect the peacetime population of the Regular Army.

"The data derived from the total sample of approximately 85,000 white males proved too unwieldy and time consuming to handle in the mechanical processes of sorting and analyzing. For this reason the analyses presented here are based on a smaller sample. It has been found that a geographically weighted subsample of approximately 25,000 white males did not differ significantly from the larger sample. Furthermore, the smaller series allows for a close approximation to the Selective Service data for geographical distribution of birthplace for men examined between November 1940 and June 1945. Thus, the 25,000 subsample should give a close approximation to the military population at the end of World War II."

The age range of the subjects was from 15 to 40+ years, with 92.16% falling in the 18-31 year range.

The statistics reported for each measurement are: Number of subjects, range, mean, standard deviation and selected percentiles from the first to ninety-ninth.

Table 35-1 presents essential measurement data from this study.

Annotator's note: This "annotation" is based upon unpublished material received by letter communication from the originating agency. It refers to no specific report, but to data obtained during the survev indicated.

Additional reference: Quartermaster Corps, Research and Development Center, Environmental Protection Division. Chest-waist Circumference Relations for 18,111 Separatee Army Males. (Partial Report of Phase I, Project No. E-59-46), Memorandum Report No. 6, 4 August 1947 (Climatic Research Laboratory).

TABLE 34 - 1

Army Anthropometric Data: Females (1946)

Measurement[1]	N	Range	Mean	S.D.	Median[2]	Percentiles 1st	5th	95th	99th
Arm Scye	8523	10.63 - 21.65	14.983	1.269	14.887	12.265	12.974	17.209	18.476
Back Waist Length	8527	10.83 - 19.09	14.907	.908	14.898	12.759	13.434	16.424	17.034
Ball Foot Circumference	1949	7.36 - 10.31	8.741	.460	8.722	7.717	8.014	9.564	9.937
Biocular	8438	3.01 - 4.35	3.552	.180	3.551	3.149	3.260	3.861	3.986
Bizygomatic	8428	4.35 - 6.00	5.149	.214	5.157	4.618	4.784	5.488	5.641
Breast Circumference	8561	27.17 - 50.79	35.082	3.036	34.681	29.413	30.794	40.758	43.630
Cervicale Height	8531	47.64 - 64.17	54.511	2.277	54.492	49.293	50.759	58.319	60.011
Cervicale-Lateral Neck Point	8528	2.36 - 5.31	3.591	.372	3.588	2.688	2.969	4.205	4.474
Chest Breadth	3350	8.46 - 16.73	11.602	.913	11.560	9.526	10.161	13.119	13.989
Chest Circumference	8536	24.02 - 46.06	30.516	2.457	30.189	26.000	27.018	35.037	37.782
Cross Back Width	3414	10.04 - 18.70	13.932	1.105	13.926	11.352	12.188	15.746	16.648
Face Length	8452	3.48 - 5.30	4.377	.263	4.374	3.791	3.958	4.819	5.125
Foot Breadth	1945	2.93 - 4.43	3.610	.223	3.603	3.092	3.249	3.989	4.147
Foot Length	1949	7.89 - 10.96	9.410	.439	9.403	8.405	8.709	10.173	10.496
Forearm Circumference	8512	6.77 - 11.89	8.924	.665	8.860	7.526	7.907	10.102	10.745
Halfway to Hip Circumference	8520	25.59 - 49.21	33.883	2.983	33.572	28.116	29.526	39.253	42.441
Hand Breadth	8505	2.38 - 3.88	3.031	.201	3.014	2.613	2.739	3.400	3.598
Hand Length	8488	5.85 - 8.21	6.886	.326	6.875	6.134	6.361	7.443	7.706
Head Breadth	8500	4.90 - 6.56	5.736	.216	5.742	5.179	5.369	6.083	6.249
Head Circumference	8518	19.68 - 24.02	21.715	.614	21.710	20.285	20.709	22.745	23.219
Head Height	8499	4.04 - 6.48	5.186	.354	5.190	4.361	4.589	5.728	6.052
Head Length	8451	6.32 - 8.05	7.232	.255	7.231	6.653	6.798	7.650	7.826
Heel Breadth	1940	1.91 - 3.01	2.349	.166	2.336	1.999	2.094	2.648	2.797
Hip Circumference	8544	28.74 - 50.00	37.498	2.663	37.211	32.372	33.629	42.285	45.254
Hip Height	8512	26.38 - 40.55	32.202	1.739	32.160	28.267	29.394	35.154	36.603

Notes: 1. Dimensions are in inches, unless otherwise marked.
2. The median is the same as the 50th percentile.

TABLE 34 - 1 (Continued)

Measurement	N	Range	Mean	S.D.	Median	Percentiles 1st	5th	95th	99th
Inseam	8532	21.65 - 36.61	28.694	1.640	28.689	24.750	26.020	31.410	32.691
Instep	1948	6.00 - 8.05	6.977	.353	6.966	6.154	6.386	7.595	7.840
Interocular	8491	.81 - 1.75	1.244	.122	1.240	.948	1.039	1.451	1.550
Lateral Neck Point-Waist	8474	13.19 - 22.24	16.775	.994	16.752	14.520	15.168	18.487	19.243
Mid Thigh Circumference	8532	12.99 - 28.74	19.357	1.970	19.230	15.152	16.392	22.798	24.594
Minimum Frontal	8432	2.85 - 4.74	3.962	.233	3.977	3.302	3.555	4.307	4.465
Nasal Root Breadth	8421	.35 - .98	.612	.094	.608	.409	.463	.782	.848
Neck Circumference	8405	10.43 - 16.34	12.530	.663	12.486	11.126	11.504	13.698	14.372
Nipple-Nipple	8413	4.53 - 13.19	7.614	.852	7.580	5.699	6.327	9.053	9.842
Nipple-Nipple Over Cervicale	8508	21.65 - 42.13	28.219	2.594	27.817	23.702	24.690	33.046	36.086
Nose Breadth	8430	.83 - 1.65	1.222	.104	1.220	.964	1.046	1.392	1.476
Nose Length	8211	1.20 - 2.62	1.877	.178	1.871	1.428	1.599	2.170	2.352
Outer Canthus Otobasion Superior	5046	2.38 - 3.88	3.061	.193	3.052	2.653	2.761	3.401	3.573
Patella Height	8412	15.16 - 22.64	18.795	.952	18.767	16.552	17.192	20.325	21.147
Shoulder-Elbow Length	8488	10.04 - 16.34	13.100	.735	13.102	11.288	11.897	14.298	14.900
Shoulder Length	8539	3.15 - 7.09	4.785	.462	4.763	3.789	4.025	5.564	5.970
Stature	8549	57.48 - 74.02	63.920	2.424	63.893	58.385	59.903	67.995	69.655
Thigh Circumference at Crotch	8131	16.14 - 31.10	22.134	2.072	21.931	17.879	19.007	25.826	27.653
Total Crotch Length	8149	20.08 - 38.98	27.683	2.276	27.502	22.835	24.318	31.681	34.252
Trunk Height	8502	17.52 - 26.18	21.169	1.093	21.164	18.576	19.439	22.965	23.746
Upper Arm Circumference	8493	6.89 - 15.94	10.132	1.098	10.006	8.037	8.546	12.139	13.202
Vertical Trunk Circumference	8096	49.21 - 72.83	59.070	2.827	58.945	53.057	54.654	64.039	66.619
Waist Circumference	8538	20.87 - 38.98	26.483	2.552	26.035	22.148	23.104	31.374	34.572
Waist Height	8523	34.25 - 48.43	40.382	1.854	40.368	36.196	37.324	43.495	44.968
Weight (lbs.)	8530	87.00 -227.00	131.865	19.965	129.381	97.112	104.708	169.858	191.944
Wrist Circumference	8541	4.72 - 7.28	5.806	.336	5.788	5.059	5.280	6.382	6.729

Notes: 1. Dimensions are in inches, unless otherwise marked.
2. The median is the same as the 50th percentile.

TABLE 35 - 1

Army Anthropometric Data: Males (1946)

Measurement[1]	N	Range	Mean	S.D.	Median[2]	Percentiles 1st	5th	95th	99th
Ankle Circumference	24297	8.07 - 13.39	10.359	.570	10.336	9.061	9.442	11.315	11.779
Arm Length	24449	24.02 - 36.61	30.480	1.390	30.463	27.244	28.243	32.830	33.833
Arm Scye	24383	13.88 - 22.15	17.088	1.173	1[illegible].023	14.499	15.279	19.131	20.108
Axillary Arm Circumference	24729	8.37 - 15.85	12.139	1.067	1[illegible].059	9.909	10.538	14.027	14.988
Ball Foot Circumference	24468	7.87 - 11.81	9.698	.504	9.692	8.546	8.878	10.548	10.924
Bideltoid	24461	13.78 - 23.23	17.949	.987	17.902	15.808	16.392	19.616	20.587
Bigonial	24432	3.15 - 5.71	4.236	.236	4.229	3.676	3.860	4.621	4.827
Bi-Iliac	24518	8.86 - 15.94	11.458	.794	11.407	9.698	10.259	12.839	13.632
Biocular	24361	2.76 - 4.72	3.631	.202	3.621	3.138	3.288	3.990	4.151
Bizygomatic	24389	4.33 - 6.50	5.473	.235	5.476	4.868	5.073	5.860	6.013
Buttock-Knee Length	24244	19.29 - 27.95	23.398	1.123	23.392	20.668	21.496	25.229	26.045
Calf Circumference	24686	10.73 - 18.60	14.081	.937	14.042	11.994	12.586	15.642	16.492
Cervicale Height	21141	50.00 - 68.90	58.740	2.383	58.737	53.240	54.814	62.675	64.363
Chest Breadth	24574	8.07 - 15.16	11.138	.771	11.108	9.301	9.952	12.447	13.150
Chest Circumference	24470	27.95 - 48.42	36.383	2.345	36.193	31.574	32.879	40.472	43.010
Chest Depth	24558	5.32 - 12.80	8.330	.747	8.278	6.774	7.200	9.600	10.536
Cross Back Width	24432	9.65 - 19.88	14.815	1.182	14.810	12.086	12.885	16.783	17.698
Crotch Thigh Circumference	24832	16.24 - 27.66	21.436	1.701	21.325	17.922	18.850	24.455	26.001
Elbow Breadth	24590	13.58 - 24.21	17.537	1.537	17.401	14.422	15.270	20.267	21.835
Face Length	24494	3.94 - 6.30	4.922	.281	4.914	4.274	4.466	5.396	5.603
Foot Breadth	24466	2.56 - 5.12	3.864	.248	3.865	3.268	3.464	4.269	4.438
Foot Length	24372	8.27 - 12.01	10.437	.476	10.436	9.312	9.653	11.241	11.541
Forearm Hand Length	24354	14.76 - 23.42	18.731	.878	18.733	16.575	17.335	20.131	20.813
Hand Breadth	24488	2.36 - 4.33	3.414	.190	3.413	2.946	3.088	3.751	3.878
Hand Length	24487	5.91 - 9.06	7.577	.364	7.571	6.743	6.995	8.181	8.469
Head Breadth	24447	4.92 - 7.09	5.987	.233	5.986	5.430	5.617	6.375	6.559
Head Circumference	24466	19.50 - 25.00	22.303	.624	22.294	20.868	21.296	23.359	23.835
Head Height	24630	3.94 - 6.30	5.163	.238	5.147	4.585	4.776	5.581	5.785
Head Length	24471	6.10 - 9.06	7.666	.277	7.666	7.009	7.210	8.130	8.330
Heel Breadth	24341	1.58 - 3.94	2.637	.210	2.627	2.141	2.296	3.005	3.206
Hip Breadth	24575	11.22 - 19.88	13.954	.896	13.872	12.230	12.656	15.496	16.728
Hip Circumference	24500	26.38 - 50.00	36.670	2.243	36.531	31.688	33.293	40.487	42.788

Notes: 1. Dimensions are in inches, unless otherwise marked.
2. The median is the same as the 50th percentile.

TABLE 35 - 1 (Continued)

Measurement[1]	N	Range	Mean	S.D.	Median[2]	Percentiles 1st	5th	95th	99th
Inseam	24497	25.59 - 39.76	32.844	1.752	32.824	28.781	29.996	35.769	37.155
Instep Length	24475	5.51 - 9.65	7.610	.441	7.616	6.544	6.876	8.334	8.678
Interocular	24359	.81 - 1.91	1.274	.123	1.267	1.004	1.089	1.491	1.618
Lower Leg Length	24664	13.98 - 23.42	17.937	1.121	17.890	15.439	16.176	19.874	20.794
Lower Thigh Circumference	24711	11.52 - 19.78	14.723	1.054	14.666	12.494	13.086	16.551	17.601
Lower Upper Arm Circumference	24769	7.58 - 14.66	9.871	.743	9.825	8.292	8.273	11.165	11.890
Mid Forearm Circumference	24492	6.00 - 13.09	9.496	.883	9.486	7.525	8.047	10.951	11.581
Mid Thigh Circumference	24446	15.06 - 26.48	19.276	1.561	19.202	15.973	16.755	21.952	23.211
Mid Upper Arm Circumference	24446	7.97 - 15.45	11.046	.929	10.993	9.072	9.606	12.685	13.536
nimum Frontal	24406	3.54 - 5.91	4.303	.233	4.296	3.778	3.918	4.698	4.901
sal Root Breadth	24348	.26 - 1.04	.561	.090	.557	.376	.410	.729	.803
Neck Circumference	24423	11.61 - 19.09	14.464	.733	14.435	12.830	13.325	15.707	16.357
Nose Breadth	24382	.81 - 2.15	1.327	.114	1.318	1.087	1.166	1.534	1.625
Nose Length	24411	1.52 - 3.09	2.179	.197	2.165	1.724	1.876	2.512	2.688
Outer Canthus Otobasion Superior	24478	2.36 - 4.33	3.363	.207	3.363	2.870	3.041	3.717	3.838
Outseam	24469	32.68 - 50.00	41.556	1.956	41.526	37.056	38.318	44.828	46.287
Patella Height	24419	15.35 - 27.16	21.617	1.087	21.615	19.026	19.825	23.452	24.307
Shoulder-Elbow-Length	24556	9.84 - 19.29	14.283	.813	14.294	12.310	12.886	15.623	16.309
Shoulder Length	24453	4.04 - 8.37	6.052	.668	6.080	4.339	4.862	7.126	7.533
Sitting Height	24352	30.32 - 41.34	35.780	1.343	35.786	32.533	33.508	38.034	39.022
Sleeve Length	24470	24.80 - 38.98	31.892	1.727	31.876	27.870	29.137	34.750	36.038
Stature	24508	59.06 - 78.74	68.470	2.516	68.461	62.711	64.333	72.642	74.481
Thigh Length	24625	9.06 - 21.65	15.028	1.313	15.028	11.940	12.829	17.169	18.248
Total Crotch Length	24434	20.08 - 38.98	28.470	2.243	28.336	23.622	25.028	32.308	35.543
Trunk Depth	24588	6.50 - 13.98	9.087	.809	9.000	7.510	7.924	10.537	11.525
Trunk Height	24715	17.72 - 27.16	23.008	1.166	23.012	20.142	21.044	24.980	25.809
Upper Arm Length	24348	9.25 - 15.94	13.129	.747	13.128	11.357	11.904	14.376	14.925
Upper Forearm Circumference	24491	7.97 - 13.48	10.536	.644	10.520	9.028	9.495	11.639	12.126
Upper Leg Circumference	24456	10.34 - 17.03	13.232	.837	13.174	11.476	11.944	14.743	15.517
Vertical Trunk Circumference	24388	49.80 - 75.00	62.076	2.664	62.004	55.824	57.828	66.648	68.988
Waist Circumference	24472	23.23 - 46.85	30.603	2.760	30.200	25.623	26.876	35.803	39.075
Weight (lbs.)	24506	95.00 -305.00	154.814	20.558	152.887	114.369	124.309	191.652	214.939
Wrist Circumference	24391	5.32 - 8.27	6.699	.405	6.690	5.791	6.040	7.383	7.691

Notes: 1. Dimensions are in inches, unless otherwise marked.
2. The median is the same as the 50th percentile.

See also: Randall, Francis E. and M.J. Baer. Survey of Body Size of Army Personnel, Male and Female: Phase I - Body Dimensions of Army Males - Methodology. Environmental Protection Division, Report No. 122, Project No. E-59-46, Quartermaster Research and Development Command, Natick, Massachusetts, 2 July 1947.

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Randall, Francis E. Age Changes in Young Adult Army Males. Human Biology, Volume 21, 1949, pp. 187-198.

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36. Randall, Francis E. and M.J. Baer. Survey of Body Size of Army Personnel, Male and Female: Phase I - Body Dimensions of Army Males - Methodology. Environmental Protection Division, Report No. 122, Project No. E-59-46, Quartermaster Research and Development Command, Natick, Massachusetts, 2 July 1947.

"This report represents the first of a series which will describe in detail the anthropometry of military males and females. Two types of considerations will be presented, metric and morphological. The metric will describe body sizes; the morphological will describe body types.

"In general, the reports will be distributed over six phases of investigation:

1. Body Dimensions of Army Males
2. Body Types of Army Males
3. Anthropometric Integration of Phases 1 and 2
4. Body Dimensions of Army Females
5. Body Types of Army Females
6. Anthropometric Integration of Phases 4 and 5."

Background information is presented relative to the reasons for the study, the methodology, the population for the study, the data desired and the conclusions resulting from the surveys. The survey was performed in 1946.

Between May and November 105,062 men at six Army separation centers were measured. Physical types were photographically recorded on 49,500 officers and men.

The actual instruments and techniques utilized in measuring the subjects are both described and photographically illustrated.

It was concluded that:
"a. A field anthropometric survey has been conducted on male military personnel, both at time of leaving the service (96,381) and at time of entry (8,681).

b. The distribution of the total population measured has been compared with the distributions of United States regional origins prepared by the Bureau of the Census and Selective Service records and has been found to show only two minor discrepancies: (1) the West South Central group and (2) the negro series are disproportionately small. However, in both cases, the series are large enough for valid statistical treatments in most analyses. Comparative values for the regional origin are presented... .

c. The data collected in this survey are considered adequate for use to:

(1) Establish specifications on the physical size of male military personnel for use in:

(a) Clothing sizing and tariffing.

(b) Determination of space requirements of personnel.

(2) Study physical type and size of male military personnel in regard to function performed in military occupations and to provide bases for personnel selection and treatment in the future."

This report is 47 pages long including one table and over 80 photographs illustrating the techniques used in measuring the subjects. The table showing the geographical composition of the sample is included with this annotation.

TABLE 36 - 1

Percentage Composition of United States Regions

Census Region	United States Census Bureau*		Selective Service**		Anthropometric Series***	
	White	Negro	White	Negro	White	Negro
New England	5.709	.070	5.917	.094	5.615	.062
Middle Atlantic	18.575	.906	21.722	1.438	18.905	.556
East North Central	18.417	.759	19.726	1.179	17.005	.200
West North Central	9.463	.236	8.688	.306	12.605	.100
South Atlantic	10.455	3.735	10.028	3.567	13.423	3.821
East South Central	6.199	2.066	6.262	2.102	6.409	1.327
West South Central	8.225	1.817	7.244	1.859	4.118	.457
Mountain	3.127	.029	2.961	.035	5.180	.015
Pacific	6.891	.103	6.710	.154	7.851	.050
Foreign	3.202	not listed	not listed	not listed	2.278	.024
Totals	90.263	9.721	89.258	10.734	93.389	6.512

*Age groups 15-34 years, 1940 Report.
**1 November 1940 - 30 June 1945.
***Number = 93,997.

37. Randall, Francis E. Survey of Body Size of Army Personnel, Male and Female: Phase 4 - Body Dimensions of Army Females - Methodology and General Considerations. Environmental Protection Division, Report No. 123, Project No. E-59-46, Quartermaster Research and Development Command, Natick, Massachusetts, 23 July 1947.

"This report represents the second of a series which will describe in detail the anthropometry of military males and females. Two types of considerations will be presented, metric and morphological. The metric will describe body sizes; the morphological will describe body types.

"In general, the reports will be distributed over six phases of investigation:

1. Body Dimensions of Army Males
2. Body Types of Army Males
3. Anthropometric Integration of Phases 1 and 2
4. Body Dimensions of Army Females
5. Body Types of Army Females
6. Anthropometric Integration of Phases 4 and 5."

Background information is presented relative to the rationale of the study, the methodology, the population for the study, the data desired and the conclusions resulting from the survey. The data presented in this report concern the methods of measurement and the general consideration of the population measured. These measurement techniques are described and a photograph of the instruments is included.

Measurements were taken at three Army camps and six different Army General Hospitals. Age, height and weight distributions are presented for Army WAC officer and enlisted groups.

It was concluded that:
"a. Sixty-four dimensions and fourteen observations were taken on 8,859 female subjects, 8,459 white, and 400 non-white, all having had previous military experience.

b. Preliminary analyses of the data on 8,259 white women for age, weight and stature have been made and are reported... . These data show that Army WAC Enlisted Women tend to be shortest and lightest, WAC Officers tend to be tallest and heaviest, as well as oldest, and Army Nurses intermediate to the other two groups in stature and weight.

c. Tests for regional differences for each group reveal that the means of weight do not vary with statistical significance throughout the United States, but that the means of stature do, with New England and Middle Atlantic groups being the shortest. These facts indicate a possible need for differential clothing size tariffs for different induction areas.

d. Differences in statures and weights between Army Nurses and WAC Officers indicate some possibility that differential tariffs may be needed for the two Officer groups.

e. These data, although few in number, indicate variabilities which may be expected to occur in native-born female populations of the United States.

f. The entire series will provide basic information which will enable clothing and equipment designers to standardize the sizes of their products for use by Army females."

This report is 36 pages long and contains three tables of data which are included with this annotation and one photograph of the anthropometric instruments employed.

TABLE 37 - 1

Statistical Values For Age in 8259 Army Females According to Nine U.S. Regions (White, Native-Born)

Values are in Years

	New England	Middle Atlantic	East North Central	East South Central	West North Central	West South Central	South Atlantic	Mountain	Pacific	Total U.S.
NURSE										
Mean	27.045	25.687	26.360	25.627	26.406	26.842	26.862	26.171	25.635	26.259
Mode	23.000	23.000	23.000	23.000	23.000	24.000	23.000	23.000	23.000	23.000
Median	25.151	23.369	24.503	24.292	24.502	25.336	25.059	24.823	24.231	24.624
Sigma	±5.216	±4.644	±4.759	±3.589	±4.853	±4.047	±5.121	±4.153	±4.195	±4.711
$S.E._m$	±.321	±.178	±.136	±.332	±.167	±.541	±.427	±.420	±.533	±.080
Range	21-47	21-46	22-48	21-39	22-46	22-38	22-44	22-44	21-44	21-48
Number	265	679	1221	118	842	57	145	99	63	3489
ENLISTED WAC										
Mean	27.185	25.636	26.563	26.712	27.501	26.675	27.148	25.922	25.837	26.443
Mode	22.000	22.000	22.000	23.000	23.000	22.000	22.000	22.500	22.000	22.000
Median	25.071	23.341	24.626	24.067	25.470	24.071	25.125	24.400	23.550	24.500
Sigma	±6.347	±5.470	±5.820	±6.219	±6.138	±6.617	±6.011	±5.005	±5.318	±5.871
$S.E._m$	±.314	±.154	±.171	±.529	±.255	±.535	±.338	±.406	±.470	±.090
Range	20-50	18-59	19-51	18-51	20-50	20-54	20-48	21-49	21-47	18-59
Number	410	1259	1160	139	581	154	317	153	129	4302
OFFICER WAC										
Mean	30.778	31.612	30.839	31.875	31.649	33.667	29.962	28.875	30.250	31.209
Mode	-	31.500	25.000	-	25.000	-	-	29.000	-	26.000
Median	29.251	31.115	29.429	31.167	30.625	35.500	28.500	28.500	27.167	29.752
Sigma	±5.869	±5.981	±5.894	±5.395	±5.836	±5.573	±6.279	±4.305	±6.933	±6.068
$S.E._m$	±.885	±.653	±.485	±1.393	±.605	±1.680	±1.256	±.898	±1.790	±.271
Range	23-44	22-51	22-52	23-42	23-47	26-45	23-48	23-40	25-48	22-52
Number	45	85	149	16	94	12	26	24	16	467

TABLE 37 - 2

Statistical Values For Weight in 8259 Army Females According to Nine U.S. Regions (White, Native-Born)

Values are in Pounds

	New England	Middle Atlantic	East North Central	East South Central	West North Central	West South Central	South Atlantic	Mountain	Pacific	Total U.S.
NURSE										
Mean	134.368	131.373	132.774	131.346	132.511	130.482	129.328	131.944	139.008	133.246
Mode	137.500	117.500	127.500	117.500	127.500	127.500	127.500	127.500	137.500	127.500
Median	132.840	127.399	129.760	125.960	130.175	127.815	127.065	127.500	136.390	129.290
Sigma	±20.664	±22.155	±20.174	±20.056	±18.808	±19.472	±20.230	±21.517	±18.993	±20.215
$S.E._m$	±1.272	±.851	±.578	±1.862	±.649	±2.602	±1.686	±2.174	±2.412	±.342
Range	96-195	90-246	90-212	91-193	95-212	103-178	94-193	100-230	95-197	90-246
Number	265	679	1221	117	841	57	145	99	63	3487
ENLISTED WAC										
Mean	133.890	132.544	133.751	129.786	134.170	133.928	131.964	132.532	133.090	132.542
Mode	127.500	127.500	122.500	117.500	127.500	127.500	117.500	122.500	112.500	127.500
Median	130.325	129.855	129.945	128.125	130.600	130.415	127.710	128.500	129.821	129.635
Sigma	±21.703	±19.875	±20.273	±17.649	±20.174	±20.803	±21.372	±21.401	±21.685	±20.585
$S.E._m$	±1.073	±.561	±.596	±1.497	±.838	±1.682	±1.202	±1.730	±1.932	±.314
Range	93-206	86-208	99-224	95-177	97-225	93-195	93-216	89-201	98-213	86-225
Number	410	1257	1159	140	581	154	317	154	127	4299
OFFICER WAC										
Mean	135.833	134.226	131.933	139.688	133.563	139.583	133.846	131.500	132.812	135.379
Mode	132.500	127.500	122.500	137.500	127.500	-	-	142.500	-	132.500
Median	132.500	131.875	130.000	135.000	128.930	132.500	132.500	135.835	131.665	131.515
Sigma	±23.119	±15.572	±16.867	±19.919	±20.329	±31.257	±16.500	±17.776	±12.052	±16.145
$S.E._m$	±3.485	±1.709	±1.382	±5.143	±2.108	±9.424	±3.300	±3.629	±3.112	±.758
Range	94-199	102-173	97-195	119-190	105-196	109-234	101-168	98-167	113-153	94-234
Number	45	84	150	16	94	12	26	25	16	468

TABLE 37 - 3

Statistical Values For Stature in 8259 Army Females According to Nine U.S. Regions
(White, Native-Born)
Values in Centimeters

	New England	Middle Atlantic	East North Central	East South Central	West North Central	West South Central	South Atlantic	Mountain	Pacific	Total U.S.
NURSE										
Mean	162.240	161.859	162.416	163.542	162.928	163.026	163.062	163.287	165.039	163.385
Mode	162.500	163.500	165.500	166.500	161.500	164.500	163.500	165.500	167.500	163.500
Median	162.283	161.790	162.312	163.575	162.840	163.300	163.154	163.751	166.125	162.754
Sigma	±6.094	±6.076	±5.907	±5.905	±5.942	±5.044	±6.147	±6.540	±6.115	±6.104
$S.E._m$	±.375	±.233	±.169	±.546	±.205	±.674	±.512	±.661	±.777	±.103
Range	140-179	138-184	145-180	149-181	143-179	150-175	145-176	147-179	152-178	138-184
Number	265	679	1221	118	842	57	144	99	63	3488
ENLISTED WAC										
Mean	161.104	161.458	161.866	162.943	162.770	163.474	162.661	162.657	162.895	162.641
Mode	159.500	163.500	160.500	159.500	161.500	161.500	163.500	163.500	160.500	159.500
Median	161.362	161.508	161.591	163.111	162.820	163.222	163.089	162.944	163.301	162.184
Sigma	±6.088	±6.252	±6.199	±5.689	±6.126	±6.211	±5.911	±6.381	±6.639	±6.246
$S.E._m$	±.302	±.176	±.182	±.483	±.254	±.502	±.333	±.518	±.587	±.095
Range	145-176	140-188	145-188	150-175	146-179	147-178	145-188	146-180	146-177	140-188
Number	407	1260	1159	140	581	154	317	153	129	4300
OFFICER WAC										
Mean	163.546	163.726	163.653	167.000	163.914	163.500	165.346	165.700	166.250	164.841
Mode	158.500	162.000	163.500	-	170.500	162.500	167.500	-	-	162.500
Median	162.625	163.334	163.250	167.000	165.000	162.333	166.000	165.500	164.000	163.763
Sigma	±6.481	±5.632	±6.294	±5.049	±5.868	±5.538	±5.134	±6.823	±7.067	±6.181
$S.E._m$	±1.000	±.618	±.516	±1.304	±.609	±1.670	±1.027	±1.393	±1.825	±.291
Range	145-175	152-177	143-184	156-177	147-174	156-173	157-176	146-178	155-180	143-184
Number	43	84	150	16	94	12	26	25	16	466

38. Randall, Francis E., Ella H. Munro and Robert M. White. Anthropometry of the Foot (U.S. Army White Male). Report No. 172, Environmental Protection Division, Quartermaster Research and Development Center, Natick, Massachusetts, January 1951.

"This study provides data on the interrelationships of dimensions of the U.S. Army white male foot for use by designers of Army lasts and footwear.

"Data obtained during an anthropometric survey of the feet of 5575 Army white men are available in a report published in 1946 by the Armored Medical Research Laboratory, Fort Knox, Kentucky (Freeman, Arthur, Everett C. Huntingdon, George C. Davis, Richard B. Magee, Valgene M. Milstead, and Charles M. Kirkpatrick. Foot Dimensions of Soldiers.). Although the original report contains many useful data, the interpretations thereof do not permit direct application by designers of lasts and shoes for the Army. In order to provide greater detail and also more directly applicable information, an intensive analysis of the original Fort Knox data has been carried out.

"The present practice of sizing and fitting shoes on the basis of Foot Length and Ball Breadth Horizontal is not the best method available from a statistical point of view. A better method would be the use of Ball Length and Ball Girth dimensions, which most accurately control the fit of the shoe because of closer interrelationships with other critical dimensions of the foot. Reference data are provided in the form of tables and a nomograph for application of these relationships in the construction of lasts and shoes. Of the 23 dimensions studied, five are highly correlated with Ball Girth and four with Ball Length. Eleven dimensions have a medium correlation with Ball Girth and nine with Ball Length. Seven dimensions show a low correlation with Ball Girth and ten with Ball Length. Of those dimensions showing low correlations with either of the two basic dimensions, the

Dorsal and Plantar Arch Heights, Foot Flare, and the Angular Orientation of the Heads of Metatarsals, probably present the greatest problems in accommodation. Only Dorsal Arch Height may be partially provided for by adjustment in the individual shoe. Of those dimensions highly correlated with Ball Length, all must be provided for without recourse to adjustment, but Ankle Girth, Lower Leg Girth, and Instep Girth, all highly correlated with Ball Girth, may be accommodated by adjustment in the shoe.

"The general conclusion reached is that the dimensions of the foot which are closely related to the two basic dimensions, Ball Length and Ball Girth, are easily accommodated, whereas those poorly related cannot be accommodated by adjustment and, therefore, must be provided for in the design of the shoe. Dimensions which probably are critical in the proper fit of shoes, and which show low correlations with Ball Length and Ball Girth, namely, the Dorsal and Plantar Arch Heights, Foot Flare, and Angular Orientation of the Heads of Metatarsals, may be expected to occur with almost as much variation for any one size as they occur in all feet. Thus, in order to obtain shoes which will fit properly, it will be necessary to construct them in such a manner as to provide for a considerable amount of independent variation in most of the dimensions studied."

The report includes three tables, two figures and two bibliographic references.

The brief descriptions of the methods of measurement, the two tables and one figure are included with this annotation.

See also: Munro, Ella H. Preparation of Anthropometric Nomographs. Environmental Protection Division, Report No. 184, Quartermaster Research and Development Command, Natick, Massachusetts, February 1952.

TABLE 38 - 1

Comparison of Foot Dimensions of Large and Small Series

Dimensions	Entire Series Mean	Entire Series 1	Series of 146 Mean	Series of 146 2	1/2
Ball Girth	9.91	.46	9.82	---	---
Ball Length	7.59	.37	7.46	---	---
Angle Line I - J	86.32°	2.90°	86.01°	2.37°	1.22
Ankle Girth	13.53	.62	13.38	.39	1.59
Ankle Length	4.38	.26	4.33	.17	1.53
Ball Breadth Diagonal	4.08	.20	4.02	.07	2.86
Ball Breadth Horizontal	3.86	.20	3.82	.09	2.22
Ball Height	1.53	.09	1.53	.07	1.29
Breadth of Three Forward Toes	2.75	.18	2.75	.16	1.12
Dorsal Arch Height	3.08	.21	3.07	.19	1.11
Fifth Toe Length	8.25	.41	8.13	.26	1.58
Foot Flare	34.37%	6.23%	34.38%	6.06%	1.03
Foot Length	10.37	.47	10.22	.18	2.61
Heel Breadth	2.75	.15	2.71	.11	1.36
Height of Great Toe Tip	.90	.09	.89	.10	.90
Instep Breadth	3.46	.23	3.41	.16	1.44
Instep Girth	10.17	.46	10.06	.26	1.77
Lower Leg Girth	8.69	.51	8.56	.37	1.38
Outside Ball Height	1.00	.08	1.00	.07	1.14
Outside Ball Length	6.28	.37	6.18	.27	1.37
Outside Ball Length Diagonal	6.77	.35	6.68	.20	1.75
Plantar Arch Height	1.12	.20	1.14	.17	1.18
Toe Height	1.08	.10	1.07	.08	1.25
Toe Length	2.78	.20	2.76	.16	1.25

Note: Means and standard deviations are in inches, except as otherwise designated.

TABLE 38 - 2

Correlations of Dimensions of the Foot

Dimensions	"r" with Ball Girth	"r" with Ball Length	"r" with Ball Girth and Ball Length
Angle Line I - J	-.064	.338	.447
Ankle Girth	.722	.693	.807
Ankle Length	.652	.732	.793
Ball Breadth Diagonal	.905	.548	.908
Ball Breadth Horizontal	.839	.417	.840
Ball Height	.526	.255	.527
Breadth of Three Forward Toes	.481	.297	.483
Dorsal Arch Height	.334	.147	.337
Fifth Toe Length	.481	.721	.729
Foot Flare	.041	-.180	.243
Foot Length	.578	.901	.908
Heel Breadth	.595	.425	.608
Height of Great Toe Tip	.254	.172	.258
Instep Breadth	.655	.553	.697
Instep Girth	.805	.551	.817
Lower Leg Girth	.705	.522	.724
Outside Ball Height	.416	.226	.416
Outside Ball Length	.364	.663	.663
Outside Ball Length Diagonal	.449	.734	.737
Plantar Arch Height	.100	-.116	.225
Toe Height	.429	.264	.431
Toe Length	.363	.309	.387

Appendix 38 - 1

Methods of Measurement

Brief descriptions of the foot measurements discussed in this report are given below for reference. The original Fort Knox report contains more detailed descriptions of the measurements, as well as photographs illustrating the methods of measurement. It will be noted that many of the measurements were obtained from photographs of the soles of test subjects' feet which were taken during the Fort Knox survey. These dimensions are illustrated in the figure, Bottom Profile of "Average" Foot. These same measurements may be taken directly on the feet with calipers.

Angular Orientation of Heads of Metatarsals (also called Angle Line I - J) - The angle between the lines formed by Outside Ball Length Diagonal and Ball Breadth Diagonal dimensions. Measured from a photograph of the sole.

Ankle Girth - Girth around the heel and dorsal junction of the foot and leg. Tape measurement.

Ankle Length - Length between the top of the heel, 65 millimeters (2.6 inches) above the floor, and the dorsal junction of the foot and leg. Caliper measurement.

Ball Breadth Diagonal - Breadth between the inside and outside balls of the foot, taken diagonally. Measured from a photograph of the sole.

Ball Breadth Horizontal - Sum of the distances from the Foot Length axis to the inside and outside balls of the foot. Measured from a photograph of the sole.

Ball Girth - Girth of the foot taken over the inside and outside balls of the foot. Tape measurement.

Ball Height - Height from the floor to the highest point over the inside ball of the foot. Caliper measurement.

Ball Length - Length from the heel to the inside ball of the foot taken parallel to the Foot Length axis. Measured from a photograph of the sole.

Breadth of Three Forward Toes - Maximum breadth from the outer edge of the great toe to the outer edge of the third toe. Measured from a photograph of the sole.

Dorsal Arch Height - Height from the floor to the dorsal surface of the foot where it joins the leg. Caliper measurement.

Fifth Toe Length - Length from the heel to the tip of the fifth toe taken parallel to the Foot Length axis. Measured from a photograph of the sole.

Foot Flare - The ratio of the distance between the Foot Length axis and the inside ball to Ball Breadth Horizontal, expressed as a percentage.

Foot Length - Length from the back of the heel to the tip of the longest toe. Measured from a photograph of the sole.

Heel Breadth - Breadth of the heel, taken 45 millimeters (1.8 inches) forward of the back of the heel. Measured from a photograph of the sole.

Height of Great Toe Tip - Height from the floor to the highest point on the tip of the great toe. Caliper measurement.

Instep Breadth - Breadth of the instep, taken in the plane of the junction of the foot and leg to include a portion of the sole which curves upward in the hollow of the arch. Measured from a photograph of the sole.

Instep Girth - Girth of the instep, taken in the vertical plane passing through the junction of the foot and leg. Tape measurement.

Lower Leg Girth - Girth of the leg, taken 125 millimeters (4.9 inches) above the floor. Tape measurement.

Outside Ball Height - Height from the floor to the highest point over the outside ball of the foot. Caliper measurement.

Outside Ball Length - Length from the heel to the outside ball of the foot, taken parallel to the Foot Length axis. Measured from a photograph of the sole.

Outside Ball Length Diagonal - Length from the heel to the outside ball of the foot, taken diagonally. Measured from a photograph of the sole.

Plantar Arch Height - Height from the floor to the point of merger of the curvature of the arch with the vertical aspect of the inner surface of the foot, taken in the vertical plane passing through the junction of the foot and leg. Caliper measurement.

Toe Height - Height from floor to highest point on the great toe. Caliper measurement.

Toe Length - Length from inside ball of the foot to the tip of the longest toe, taken parallel to the Foot Length axis. Measured from a photograph of the sole.

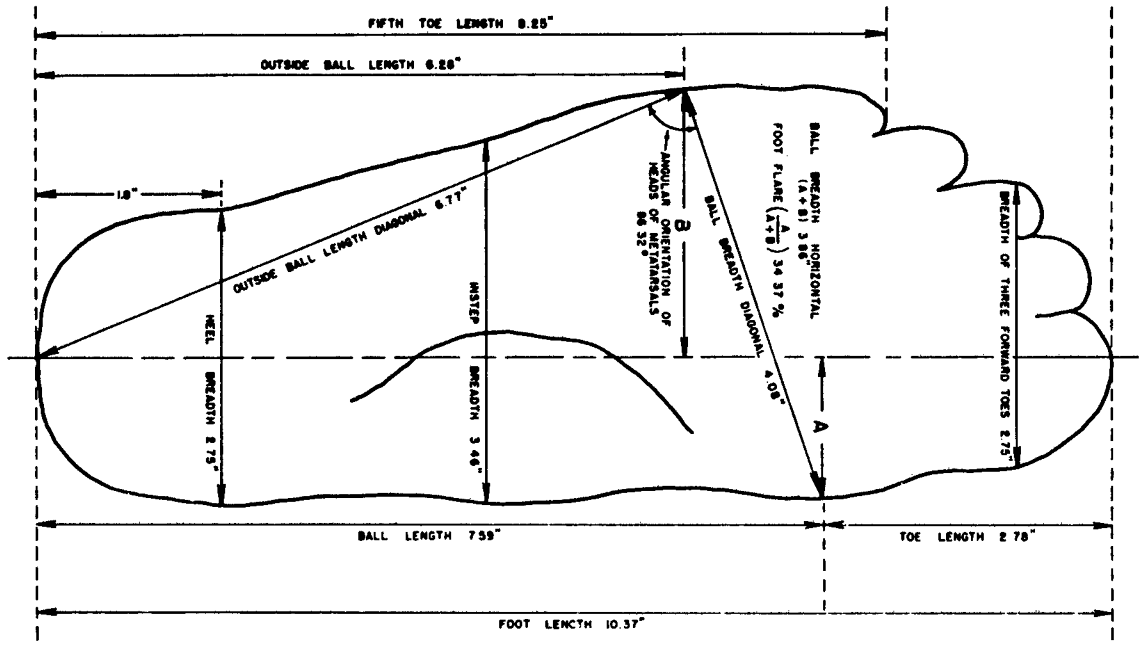


FIGURE 38 - 1

Bottom Profile of "Average" Foot

39. Shanklin, William M. <u>Anthropometry of Transjordan Bedouin with a Discussion of Their Racial Affinities</u>. <u>American Journal of Physical Anthropology, New Series, Volume 4, No. 3, September</u> 1946, pages 323-375.

This study reports the results of fifteen measurements, fifteen indices and numerous observations on 60 to 70 members of two Bedouin tribes, the Beni Sakhr and the Howeitat. The definitions of measurements and indices have been published in another of the author's works (Shanklin, William M. <u>Anthropometry of Syrian Males</u>,) and are not reported in the present article. The article also discusses certain racial problems of these peoples. Two tables of measurement data on the subject groups are included in the annotation.

The article's 52 pages include 4 tables, 4 plates and 14 bibliographic references.

40. Anonymous. Increase in Stature of American Men. Statistical Bulletin, Metropolitan Life Insurance Company, Volume 25, No. 11, November 1944, pages 1 and 2.

This article discusses a government study (N of original study unspecified in the present article) determining the stature of American men. "Stature shows distinct signs of increase in the present generation. The average height of men in the ages 20 to 29 examined at induction stations for the armed service in May 1943 was 68.15 inches (without shoes). This figure is about two thirds of an inch more than the average of 67.49 inches for the first million draftees of ages 21 to 30 examined at mobilization camps in the last World War, in 1917. The figure cited for 1943 is based upon an analysis of data recently published by the Office of the Surgeon General of the Army, and is adjusted to allow for the omission of cases inducted into the Navy, for which figures are not available.

"Not only has the average height increased over this period, but as one would naturally expect, the proportion of tall men among the 1943 selectees was also greater than among those of the last war. In the age group 20 to 30 years, the proportion of men 5 feet 10 inches or over among the recent selectees was 27.5 percent, as against 22.4 percent reported for the men in 1917. The proportions of six-footers were 8.8 and 6.5 percent respectively. In other words, the proportion of six-footers among young men is about one third greater at present than it was a quarter of a century ago.

"An inspection of the facts for men of different ages at the induction examinations for the present war also clearly shows this trend, inasmuch as the older men were born at an earlier period. The average heights, according to age, are as follows:

Under 20 years	68.02 inches
20-24	68.15 inches
25-29	68.14 inches
30-34	67.83 inches
35 and over	67.54 inches

"It will be noted that the older men are of somewhat lesser stature than the younger, and there is a sustained gradual increase from the older to the younger men, except as regards the youngest group, for whom growth is evidently not quite complete. Even so, the selectees 35 years old and over (almost all of whom are 35 to 38) today are a little taller than the average at ages 21 to 30 in the first World War, who were born about 15 years earlier. It is also noteworthy that the average stature of those 18 and 19 years old today is actually a little greater than that of those over 30.

"In the separate age groups also, the increasing frequency of taller men shows itself. At ages 20 to 24 there were 28.1 percent 5 feet 10 inches or over. This ratio declined gradually with age, and at ages 35 and over a little over a fifth (20.3 percent), were 5 feet 10 inches or over. Six-footers comprised 9.1 percent of the men between 20 and 24 as compared with only 5.8 percent of those 35 or over. Even at ages under 20, the proportion of tall men was slightly greater than at ages 30 to 34 and appreciably greater than among those over 35.

"Supplementing this information from the records of examinations of selectees are some interesting studies of the heights of school children. For example, comparative series of observations among elementary school children in Toronto show that the typical elementary school boy or girl of six in 1939 was actually two inches taller than the child of the same age in 1892. At 9 years of age this difference was about three inches, and at fourteen about 3 1/2 inches for boys, and a little over two inches for girls. Thus the typical six-year old child in 1939 was actually a shade taller than the typical seven-year old in 1892, and the typical thirteen-year old in 1939 was about an inch taller than the typical fourteen-year old in 1892. In part, these differences may represent accelerated growth and early approach to full stature, the ultimate difference, in adult life, being somewhat less than that found at the rapidly growing ages.

"There can be no question but that these very favorable findings with regard to increase in stature reflect the improvement in general health and nutritional conditions over recent decades. The alarm which has been voiced by some over the high rejection rates in our Army, quite overlooks the fact that standards of rejection are to some extent arbitrary and subject to adjustment according to conditions and the judgment of those directing the formation of the armed forces."

The article is two pages long, the data generally being incorporated into the text. The report includes one unnumbered table, but no figures. One bibliographic reference is made to "data recently published by the office of the Surgeon General of the Army."

41. Anonymous. Is the Average Height of American Women Increasing? Statistical Bulletin, Metropolitan Life Insurance Company, August 1938, pages 3 and 4.

This article discusses a number of studies reporting data on the height of American women. (The N's of the original studies are not specified in the present article.) "There is a common impression that the typical American woman has been growing taller. Actually, evidence is somewhat conflicting. Figures from life insurance material show such a change in a very limited degree at most. A recent study of women accepted for 'standard' insurance between 1922 and 1934 in the Metropolitan Life Insurance Company shows that the average height (with shoes) was 5 feet 4 1/4 inches in middle adult life when full growth has been attained. This figure is identical with that of two earlier Life insurance studies based on the material of several companies, the first covering the years 1885-1908 (largely, however, 1900-1908) and the second covering the period 1909-1927.

"The recent study of women insured in the Metropolitan further showed that the average height increased, as age advanced, to a maximum in the age group 45 to 49. These results, too, argue against an increase in average height in recent years, because otherwise the averages would decline with age (that is, with receding date of birth), at least after age 20, by which time women have certainly reached their full stature.

"A different picture is presented by data from several other sources, which suggest an increase in height. One of the best of these studies was that made by Bowles comparing the heights of college graduates of a generation ago with those of their offspring who attended the same college. His analysis of data of four women's colleges--Vassar, Wellesley, Smith, and Mount Holyoke--showed an increase from 161.6 cm. for mothers to 164.5 cm. for daughters, an increase of slightly less than 3 cm., or 1 1/8 inches.

"Other data from college sources, based on the average heights of women at entrance, also show significant increases. At Stanford University the average increase over a period of 30 years was 1.2 inches; at Vassar, 1 1/2 inches in 37 years; and at Smith, about 1/2 inch in 22 years. Similar in character are figures for Barnard women at graduation. The 1935 graduating class averaged slightly over one-half inch taller than the class of 1925.

"Unfortunately there are no good general data for this country, based on broad samples of the population over long periods of time, aside from the insurance data already quoted. Reference should be made, however, to the work of Boas, who showed that the native-born descendants of immigrants tended to be taller than their parents and to conform to the body measurements of the natives of the country to which the parents had immigrated.

"On the surface the data from insurance and other sources appear to be contradictory. But this contradiction may be only apparent. In the first place, the data showing an increase in average height are based on selected, homogeneous samples of the population. The insurance material is, on the other hand, a broad and increasingly large sample of the general population, more especially of the urban population, which is a heterogeneous and changing mixture.

"The average heights of the different race stocks which make up the population vary materially. They are generally higher for western European stocks than for southern and eastern European stocks. Moreover, there has been a definite change in the proportion of the various race stocks composing our population. Fifty years ago the population contained an overwhelming proportion of persons of western European stocks. With the large immigration of the pre-War period, especially from 1880-1914, from southern and eastern Europe, and with the high birth rates which prevailed among these immigrants, persons of southern and eastern European origin have formed an increasingly large proportion of our population. With no other factor operating, the increasing proportion of persons of these shorter stocks in our population would tend to bring about a decrease in the average height. The fact that there has been little, if any, change over a period of years, as shown by the insurance figures, may be an indication that the new generation of southern and eastern European origin are taller than their parents. On this supposition, while the averages for both groups have advanced, the increased proportion of the shorter race stocks in the total population has nullified an increase in the combined averages. Possibly in the insurance data the increased proportion of these shorter groups is particularly accentuated."

The article concludes that, all considered, the average height of women is probably increasing, but that average height is unlikely ever to exceed that of "certain favorably situated groups today, such as college women."

The article is two pages long. There are no tables or figures, the data being incorporated into the text. There are several allusions to other studies but no specific references.

42. Anonymous. The Stature of American Women. Statistical Bulletin, Metropolitan Life Insurance Company, March 1942, pages 9 and 10.

The article discusses some of the findings of a government study (N of original study unspecified in the present article) determining the stature of American women. "The recent Government study (O'Brien R., & Shelton, W.C. Women's Measurements for Garment and Pattern Construction.) made in 1939-1940, gives the average height of American women as 5 feet, 3 1/6 inches. This relatively low figure creates a false impression in that the measurements were made in stocking feet, whereas the commonly quoted average is based on measurements in shoes. If allowance is made for this, the comparable average for this new study would be 5 feet, 5 inches, since 2 inches is a fair allowance for the height of heels of women's shoes. Apart from that, this new study shows a marked variation in height with age. Thus, girls of 18 and 19 averaged 63 3/4 inches in height (without shoes) and those between 20 and 24 not much less. Moreover, in several important respects, the sample of 10,000 women used in this study was biased, and the net result was to yield a set of averages which, as regards height at least, are too low. For example, this sample contained a disproportionate number of such groups of women as those from cities, the Eastern seaboard, and low-income families, and, as the detailed analysis showed, the average height of such women is distinctly low, as compared with the general population.

"What is most important, however, is the fact that despite its deficiencies the study confirms others, including one made by the Metropolitan Life Insurance Company a few years ago, in showing that American girls today are as a class distinctly taller than their mothers. For example, the averages at the ages between 18 and 25 were about one full inch greater than the averages between 45 and 55. Furthermore, the average height of all the women in the new study was greater, age for age, than the average heights of women accepted for insurance in the Ordinary Department of the Metropolitan during the years 1922 to 1934. These increases in average heights are the more remarkable since women of the shorter European stocks have come to form an increasing proportion of our female population."

The article ascribes the increase in women's height to an improvement in nutrition in the childhood of that generation.

The article is one page long. There are no tables or figures, the data being incorporated into the text. There is one bibliographical reference.

43. Best, William R. and W.J. Kuhl. Estimation of Active Protoplasmic Mass by Physical and Roentgenological Anthropometry. Report No. 114, Medical Nutrition Laboratory, 9937 TSU-SGO, United States Army, Chicago 9, Illinois, 5 September 1953.

Purpose: "To develop simple and reliable methods for the measurement of active protoplasmic mass in man."

Subjects: Measurements were made on healthy young men (N = 22) who were officers or enlisted soldier personnel of the Army Medical Nutrition Laboratory. Ages ranged from 21 to 39.

Methods:

Physical measurements were usually taken in the morning. These included height, weight, anterior superior iliac spine height, span, acromio-olecranon length, chest girth, various limb girths, and a series of skinfold measurements.

"Roentgenograms of the right brachium were taken on 14" x 17" chest films using standard chest technique. Subjects were positioned with their backs to the film and their arms abducted approximately 30° from the vertical. Forearms were supinated, and the lateral chest wall was included in the exposure. A lead strip graduated in cm, and in 2 mm intervals in the mid-portion was fixed to the casset holder approximately 1 1/2" from it. This rule appeared on the roentgenograms, and, by being located at about the same distance from the film as the humerus, corrected for divergent distortion. All measurements were made in relation to the image of the lead rule. A longitudinal line was drawn from the trochlear groove to the furthest extent of the head of the humerus. The humerus length was taken as the distance between these two points. Perpendicular lines were drawn 2/5 and 2/3 of the distance from the trochlea to the head. The muscle width and skin and subcutaneous thicknesses were measured along the former perpendicular, and the bone width along the latter. These two sites were chosen after perusal of all films because they most consistently reflected what appeared to be about average dimensions of the particular components, and because they in no cases intersected with other confusing shadows such as those occurring at the junction of the biceps and deltoid muscle shadows.

"Basal oxygen consumption was determined with clinical-type bellows machines (Sanborn) in a closed circuit. Soda lime was used to absorb the carbon dioxide. At least two determinations were made on each man before breakfast in a quiet air-conditioned room after at least a half hour of rest.

"Urinary creatinine excretion was determined on three successive days for each man. Collections were for a four-hour period from 0630 to 1030 each morning, the exact times of void-discard and void-collect being noted in each instance. Volumes and concentrations were measured to derive the twenty-four hour excretion rate. The method of Peters was used for the analysis of creatinine."

Conclusions:

(1) "Oxygen consumption appears superior to urinary creatinine excretion for the metabolic estimation of active protoplasmic mass.

(2) "Lean body mass appears superior to body weight, surface area, and various other anthropometric estimates of active protoplasmic mass.

(3) "Several methods for the anthropometric estimation of active protoplasmic mass are developed; these warrant further study.

(4) "The use of basal oxygen consumption for the standardization of other anthropometric estimates of active protoplasmic mass is feasible and to be recommended."

This report is 18 pages long and contains two tables, five figures, 12 formulas and a bibliography of 18 references. Data included with annotation.

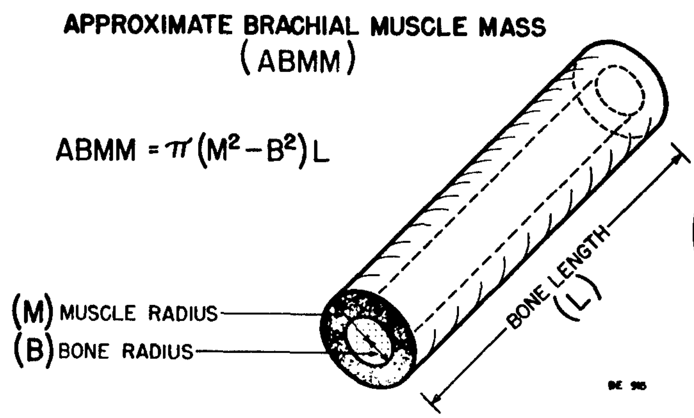


FIGURE 43 - 1

Approximate Brachial Muscle Mass

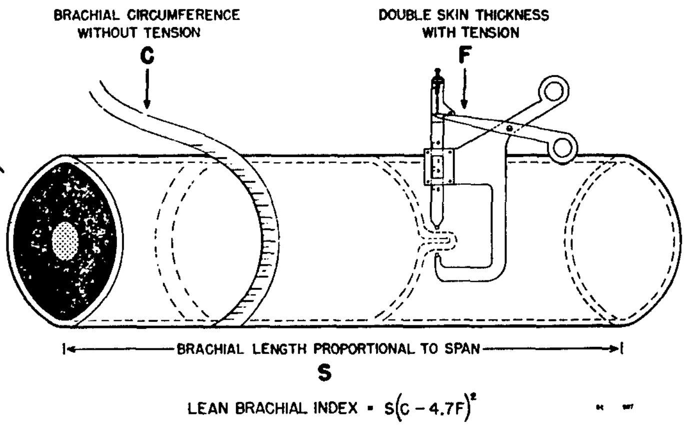


FIGURE 43 - 2

Lean Brachial Index

TABLE 43 - 1

Anthropometric and Metabolic Data on Twenty-two Healthy Men

Man No.	Initial	Age	Height cm.	Weight kg	Iliac spine height cm.	Span cm.	Surface area sq. m.	Chest girth cm.	Abdom. girth cm.	Brach. circum. cm.	Antebrach. circum. cm.	Calf circum. cm.	Elbow width cm.	Wrist width cm.	Knee width cm.
1	W. Be.	30	170.8	74.0	100.5	176.3	1.86	87.0	87.5	30.5	26.5	36.0	7.0	5.4	9.5
2	D. Do.	24	189.2	98.1	107.5	193.5	2.28	96.5	95.5	33.0	31.0	40.8	7.7	6.1	10.0
3	K. Br.	24	181.7	76.5	106.5	195.0	2.00	87.9	78.0	27.2	27.0	38.0	7.2	6.2	9.7
4	L. Ca.	22	171.0	72.4	105.0	184.0	1.84	89.5	81.5	30.2	28.4	39.0	6.5	5.6	9.6
5	T. Cu.	24	172.0	63.0	101.0	179.5	1.74	78.7	76.1	25.5	24.7	35.2	6.3	4.8	9.1
6	W. De.	23	163.2	65.6	96.0	171.0	1.70	85.8	77.5	27.5	26.6	35.5	6.5	5.0	9.5
7	L. De.	23	168.3	56.0	97.5	175.5	1.62	77.8	70.9	25.5	25.5	34.5	6.3	6.0	9.6
8	F. De.	29	170.3	76.6	96.5	175.5	1.88	96.2	85.8	28.4	28.1	36.9	6.5	5.5	9.1
9	D. Do.	23	185.5	85.0	114.0	186.5	2.10	92.5	90.8	30.1	29.0	38.2	7.1	5.8	9.4
10	J. Dr.	25	164.5	68.8	96.5	172.0	1.75	88.6	79.5	28.8	27.5	35.0	6.0	5.2	10.0
11	J. Fa.	21	177.8	98.4	103.0	181.5	2.18	101.0	96.8	33.6	30.5	41.1	7.0	6.0	9.8
12	C. Ga.	24	178.5	66.0	109.0	188.0	1.82	85.5	74.1	25.8	25.2	35.8	7.1	5.7	9.5
13	M. Gr.	33	180.4	63.6	105.0	186.0	1.80	86.4	75.5	24.2	26.4	34.5	6.3	5.6	9.5
14	T. Hu.	28	158.8	63.8	92.5	161.5	1.65	87.5	80.4	28.0	25.0	35.0	6.5	5.7	9.0
15	J. La.	26	177.2	70.0	105.5	186.0	1.86	86.3	77.5	25.7	26.2	35.5	6.7	5.7	9.5
16	R. Po.	36	166.5	68.5	90.0	167.0	1.76	90.5	78.5	25.5	26.4	36.0	6.2	5.5	9.6
17	J. Re.	39	177.8	67.8	98.5	179.0	1.84	84.2	70.8	27.0	25.2	37.0	6.2	5.6	9.3
18	F. Sa.	22	188.7	83.7	109.0	185.0	2.22	91.8	84.5	29.6	28.4	36.4	7.1	6.0	9.6
19	J. Sm.	22	173.4	61.3	102.0	181.0	1.73	79.5	76.6	24.3	24.5	34.5	6.2	5.8	9.5
20	R. Ta.	37	169.0	56.9	95.0	177.0	1.64	80.4	73.0	25.5	24.8	31.7	6.4	5.0	9.2
21	P. We.	32	173.5	63.7	101.5	182.0	1.76	85.9	80.5	27.4	26.4	34.7	6.0	5.1	8.6
22	W. Ku.	29	174.8	87.0	105.0	177.5	2.12	93.3	92.8	32.4	29.2	39.2	6.8	5.6	9.8
Mean		27.1	174.22	72.14	101.68	180.1	1.870	87.85	81.10	27.99	26.93	36.39	6.62	5.59	9.47

TABLE 43 - 1 (Continued)

Man No.	X-Ray							Oxygen consumption	4 hr. creatinine excretion (mg./24 hr.)			
	Humerus length cm.	Humerus width cm.	Medial skin cm.	Lateral arm skin cm.	Muscle width cm.	A.B.M.M.	Lean Brach. mass	cc./min.	1st	2nd	3rd	Mean
1	32.3	2.0	0.4	1.3	7.5	1306	1403	219	1591	1424	1174	1396
2	36.4	2.7	0.45	1.3	8.8	2010	2216	304	1657	2318	2340	2105
3	35.3	2.8	0.15	0.2	8.5	1788	2005	263	2210	1824	2670	2235
4	31.5	2.5	0.4	0.85	7.9	1370	1526	243	1712	1824	1800	1779
5	30.6	2.1	0.3	0.85	6.7	974	1080	200	1593	1500	2031	1708
6	30.0	2.3	0.25	0.6	7.9	1350	1469	229	1950	2047	2090	2029
7	30.5	2.3	0.15	0.2	7.6	1260	1385	208	1520	1405	1457	1461
8	31.4	2.3	0.45	0.55	7.3	1185	1315	248	1943	1998	1844	1928
9	36.2	2.6	0.45	0.65	7.9	1583	1773	257	2163	2058	2036	2086
10	30.0	2.7	0.3	0.65	8.3	1449	1602	236	1583	1808	1274	1555
11	32.1	2.6	0.9	1.05	8.4	1615	1780	300	2024	2445	1746	2078
12	35.1	2.3	0.2	0.35	7.9	1580	1719	232	1765	465	1704	1311
13	33.9	2.2	0.2	0.3	7.1	1220	1343	222	1723	1732	1567	1671
14	27.1	2.3	0.55	0.55	7.4	1055	1166	212	1797	1686	1440	1641
15	33.1	2.3	0.25	0.35	7.6	1371	1503	230	1838	1832	1957	1876
16	28.4	2.5	0.35	0.65	7.1	993	1125	220	1477	1398	1250	1375
17	31.8	2.0	0.35	0.8	7.7	1385	1482	215	547 543	277 426	271	413
18	34.6	2.4	0.25	0.65	8.4	1768	1916	280	3240	2195	2150	2528
19	32.6	2.2	0.3	0.7	6.5	959	1083	178	1473	1419	1677	1523
20	32.4	2.3	0.45	0.55	7.2	1187	1320	212	1367	1600	1174	1380
21	31.6	2.0	0.4	0.95	8.0	1493	1587	161	855	1314	1395	1188
22	33.6	2.5	0.7	1.1	8.1	1553	1711	233	1759	2280	1920	1986
Mean	32.30	2.36	0.37	0.69	7.72	1385.5	1574.3	232.1	--	--	--	1696.4

Man No.	Ankle width cm.	Abdom. skinfold cm.	Chest skinfold cm	Back skinfold cm.	Thigh skinfold cm.	Dorsal Arm skinfold cm.	Lateral Arm skinfold cm.	Medial Arm skinfold cm.	% Body Fat	Lean Body Mass kg.	Lean Brach. index
1	6.6	1.8	1.5	1.8	1.2	1.3	1.7	0.9	12.0	64.9	1.048
2	8.2	1.5	1.2	1.65	1.3	1.1	1.4	0.55	10.0	88.3	1.499
3	7.7	0.6	0.45	0.73	0.7	0.4	0.4	0.3	3.0	74.2	1.250
4	7.0	0.9	0.5	1.0	1.2	0.9	1.3	0.3	6.0	68.1	1.241
5	6.0	1.2	0.55	0.75	0.65	0.75	1.0	0.2	6.0	59.2	0.867
6	6.5	1.15	0.8	1.1	1.3	0.65	0.6	0.5	6.5	61.3	1.021
7	7.5	0.4	0.35	0.5	0.4	0.35	0.35	0.2	2.5	54.6	0.999
8	7.0	1.3	1.3	1.5	1.1	0.7	1.2	0.4	8.5	70.[illegible]	1.107
9	7.0	1.5	1.5	1.2	1.25	0.9	1.35	0.5	10.0	76.5	1.248
10	6.6	1.0	0.7	0.9	0.75	0.55	0.7	0.2	5.5	65.0	1.182
11	8.0	2.7	1.35	2.1	1.5	1.6	1.6	0.6	13.5	85.1	1.234
12	6.7	0.55	0.35	0.8	0.65	0.5	0.4	0.25	3.5	63.7	1.034
13	7.8	0.35	0.35	0.55	0.35	0.35	0.35	0.25	2.5	61.9	0.947
14	6.7	1.15	1.2	1.2	0.85	0.85	1.3	0.25	8.5	58.4	0.930
15	7.1	1.05	0.45	0.8	0.6	0.6	0.45	0.2	5.0	66.5	0.974
16	7.2	1.8	1.3	1.25	0.5	0.8	0.8	0.25	9.0	62.3	0.789
17	7.4	0.8	0.25	0.8	0.7	0.8	0.8	0.2	4.5	64.6	0.967
18	8.0	0.85	0.4	1.15	0.9	0.9	1.05	0.25	6.0	78.6	1.191
19	6.5	1.0	0.8	1.0	1.3	0.9	1.05	0.35	7.0	57.0	0.729
20	6.7	0.8	0.5	0.9	0.6	0.5	0.5	0.2	4.0	54.6	0.949
21	6.7	1.25	0.9	0.85	1.2	0.95	0.95	0.25	8.0	58.7	0.958
22	8.2	1.85	1.0	1.95	1.1	1.4	-	0.75	10.5	77.7	1.183
Mean	7.14	1.16	0.80	1.11	0.91	0.81	0.92	0.36	6.91	66.84	1.061

TABLE 43 - 2

Correlations and Regressions Between Anthropometric and Metabolic Estimates of Active Protoplasmic Mass in Twenty-two Healthy Men

Metabolic Estimate (Y)	Oxygen Consumption (cc's/min.)							
Anthropometric Estimate (X)	r	p	95% Confidence Limits of r		Prediction Equations			
					$\hat{Y} = a_1 + b_1X$		$\hat{X} = a_2 + b_2Y$	
					a_1	b_1	a_2	b_2
Lean Body Mass (kg.)								
By skinfolds	.885	<.001	.739	.952	16.9	3.22	10.4	0.24
By height/girth ratio	.863	<.001	.693	.942	27.8	3.04	10.4	0.24
Body Weight (kg.)	.838	<.001	.643	.931	55.4	2.45	5.6	0.29
Height (cm.)	.543	<.01	.157	.785	-178.1	2.35	145.1	0.13
Surface Area (sq.m.)	.804	<.001	.579	.916	- 35.2	142.9	0.82	0.0045
Lean Brachial Index	.824	<.001	.618	.925	46.3	0.0016	7700.	423.9
Lean Brachial Mass (cu.cm.)	.737	<.001	.457	.884	103.9	0.084	25.0	6.44
Approximate Brachial Muscle Mass (cu.cm.)	.708	<.001	.408	.870	109.5	0.09	71.3	5.66
Creatinine Excretion (mg./24 hr.)	.668	<.001	.328	.852	143.2	0.053	-267.3	8.35

Metabolic Estimate (Y)	Creatinine Excretion (mg./24 hr.)							
Anthropometric Estimate (X)	r	p	95% Confidence Limits of r		Prediction Equations			
					$\hat{Y} = a_3 + b_3X$		$\hat{X} = a_4 + b_4Y$	
					a_3	b_3	a_4	b_4
Lean Body Mass (kg.)								
By skinfolds	.610	<.01	.253	.821	-199.0	28.36	44.6	0.013
By height/girth ratio	.560	<.01	.186	.797	1.6	25.22	46.0	0.012
Body Weight (kg.)	.574	<.01	.200	.802	151.0	21.42	46.1	0.015
Height (cm.)	.358	>.05	-.085	.678	-1755.9	19.81	163.2	0.0065
Surface Area (sq.m.)	.591	<.01	.225	.810	- 814.8	1342.5	1.43	0.00026
Lean Brachial Index	.549	<.01	.166	.788	251	0.0136	68,650.	22.10
Lean Brachial Mass (cu.cm.)	.379	>.05	-.052	.690	854.	0.554	1081.	0.259
Approximate Brachial Muscle Mass (cu.cm.)	.437	.03	.017	.725	730.8	0.697	921.8	0.273
Creatinine Excretion (mg./24 hr.)	-	-	-	-	-	-	-	-

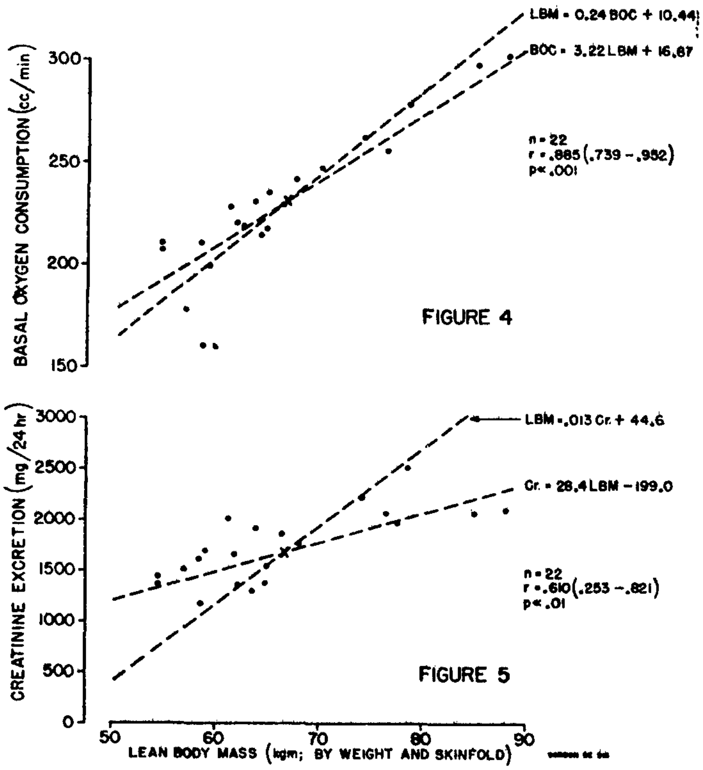


FIGURE 43 - 3

Relation of Lean Body Mass to Basal Oxygen
Consumption and to Urinary Creatinine Excretion

44. Bradley, H. Foot Measurement: For Mass Production of Footwear. Paper presented at the Commonwealth Conference on Development, Design and Inspection of Clothing and General Stores, 2nd, London (no date).

This paper gives a general overview of the progress that has been made in the past two decades in determining the "sizings" and "fittings" of shoes to be standardized for mass production. Short discussions are given of the work of such geographically dispersed organizations as the Boot Trade Research Association and the British Boot and Shoe Research Association (Great Britain), the Armored Medical Research Laboratory and the Bureau of Home Economics (U.S.A.), The Leather Industries Research Institute (South Africa), the Central Research Institute for Industry (Russia), and the Shoe Research Organization (Sweden).

"The more accurate determination of correlation between foot length and girth ...has led in practice to important advances in the gradation of lasts from size to size." There is an increased recognition throughout the world of the "importance of mass measurement towards the rational construction of lasts."

"...It should be admitted that, although a shoe that is the wrong size in some respect is bound to be uncomfortable, a knowledge of the dimensions of a foot is not by itself sufficient to ensure a properly fitting shoe. The craftsman's skill must be invoked to make good use of the measurements. In the making of his last he is able to take into account such other factors as the type of shoe, the materials of which it is to be made, and the use to which it is to be put. To illustrate this point we have only to consider the obvious difference between the lasts for a field service boot and a city shoe for the same person."

Regarding the problem of providing a limited (but adequate) variety of lasts for a population, "no one so far has successfully controverted the traditional practice of grading lasts according to 'sizes' (length) and 'fittings' (joint girth)." Improvement in the application of the details of the method are possible, however. For example, "the conventional size interval of 1/3 of an inch should be reconsidered. It may be too large whilst the half-size interval is uneconomically too small."

The paper is five pages long. There are no tables, figures, or data. "A conference such as this is evidently much more concerned with principles and policy than with technical details."

45. Brues, Alice M. Regional Differences in the Physical Characteristics of an American Population. American Journal of Physical Anthropology, New Series, Volume 4, No. 4, December 1946, pages 463-481.

"The study includes 3075 white enlisted men measured by the Chemical Warfare Service, representing all sections of the United States. Stature and eight head and face measurements have been correlated with state of birth and national extraction. Cephalic index, head length and breadth, and nose breadth, afford the clearest differentiation both for nationality of origin and for place of birth within the United States. Regional differences are less marked than those associated with national extraction, but are statistically considerable. Residence in the United States appears to have effected an increase of stature, at least in the shorter European stocks, with a corresponding slight decrease in cephalic index: certainty on this point is prevented by ignorance of selective factors in immigration. Differences in national extraction between different areas of the United States are found to be considerable, reflecting the historical sequence of migrations. The physical differences of the various regions appear to be primarily determined by the distribution of the various European stocks which settled them. Traces of the aboriginal population are indicated in only one area."

The ten tables, included in the 18 pages of this article, present the age distribution, regional designations and representativeness of the series, twenty-five measurements, a classification of national extractions and certain data in terms of birthplace and national extraction. Three bibliographic references are noted. Three tables are presented herein.

TABLE 45 - 1

Age Distribution

AGE (YEARS)	PER CENT	AGE (YEARS)	PER CENT
16–17	.1	28–29	7.5
18–19	16.7	30–31	6.7
20–21	15.6	32–33	6.8
22–23	12.5	34–35	5.8
24–25	12.2	36–37	4.9
26–27	9.1	38 and over	2.2

TABLE 45 - 3

Regional Representativeness of the Series

BIRTHPLACE	PER CENT OF NATIVE BORN	PER CENT TOTAL POPULATION, 1920 (APPROXIMATE AVERAGE BIRTH DATE OF SERIES)
New England	5.6	7.7
Middle Atlantic	23.5	22.8
East North Central	15.8	22.1
West North Central	8.5	12.9
South Atlantic	20.9	10.2
East South Central	17.5	6.7
West South Central	4.9	8.6
Mountain	1.8	3.4
Pacific	1.5	5.6
Foreign-born (per cent of total)	2.9	...

TABLE 45 - 4

Chemical Warfare Service Series, Total

MEASUREMENT	MEAN	STANDARD DEVIATION	COEFFICIENT OF VARIABILITY	RANGE
	mm.	*mm.*		*mm.*
Head length (1)[1]	195.03	6.92	3.55	165–218
Head breadth (3)	152.84	5.62	3.68	134–175
Bitragion (5)	141.49	5.56	3.93	121–168
Minimum frontal (4)	109.82	4.83	4.40	91–129
Bizygomatic (6)	139.83	5.34	3.82	122–159
Bigonial (8)	104.73	5.59	5.34	86–127
Tragion-nasal root	122.00	4.50	3.69	106–139
Tragion-subnasale	126.58	4.97	3.93	107–148
Tragion-supramentale	132.63	5.35	4.03	112–151
Tragion-anterior chin projection	144.14	5.93	4.11	119–165
Crinion-menton (17)	185.45	9.28	5.00	152–231
Crinion-nasion (24)	63.23	7.72	12.21	35–94
Nasion-menton (18)	123.78	6.71	5.42	101–151
Nasion-subnasale (21)	54.51	3.83	7.01	41–70
Nasion-pronasale (23)	51.31	4.07	7.93	38–69
Nasion-mouth slit (19)	76.68	4.49	5.86	60–101
Bimalar (7a)	109.56	6.48	5.91	86–133
Biocular (10)	91.46	4.16	4.55	70–108
Interpupillary (12)	62.83	3.84	6.11	47–79
Interocular (9)	31.84	2.66	8.35	20–43
Nose breadth (13)	35.10	2.73	7.78	21–56
Mouth breadth (14)	50.08	3.34	6.67	36–63
Ear implantation (32)	49.97	4.07	8.14	38–67
Ear length (29)	63.90	3.98	6.22	49–78
Head circumference (45a)	566.24	15.54	2.76	504–617
Number of cases	3075			

[1] Numbers in parentheses refer to standard measurement descriptions as given by Martin ('28).

46. Bullen, Adelaide K. (Harvard University). Vocational Incidence of Seven Body Types in 547 U.S. Army Women. Office of the Quartermaster General, Research and Development Branch, Military Planning Division, Contract W44-109-qm-1078, May 1948.

Purpose: "To determine whether there are distinct constitutional types of women who engage in particular types of military activities and whether there are any desirable selection procedures which might be utilized in the future for the benefit of the Armed Services."

Subjects: WAC and Nurse volunteers (N = 547) from six Army General Hospitals constituted the sample. The breakdown by race is as follows:

Whites, N = 518
Negroids, N = 27
Mongoloids, N = 2

Ages range from 20 to 56 years; 85% of the women are 35 years old or younger. In the total sample, 89% are single.

Procedure: The anthropometric techniques used were those of Randall. In all, 38 measurements were taken on each subject.

"Seven major types of body build have been distinguished in this series of women by grouping individuals of similar, although not identical, bodily characters. For the purpose of the present study, the categories and descriptive terms listed in Table 46 - 1 will be used. These categories are based on Sheldon's criteria, as these have been modified by Bullen and Hardy, and Hooton and Seltzer.

TABLE 46 - 1

Descriptive Terms For Seven Major Types of Body Build Found in Army Women

Descriptive Term (Used for convenience)	Equivalent Body Type Categories	Brief Description of Types
FAT	ENDO	SOFT, ROUND pronounced. Amounts of other trends: varying, usually low.
MUSCULAR	MESO	BIG-BONED, MUSCULAR pronounced. Amounts of other trends: varying, moderate or low.
THIN	ECTO	DELICATE, LINEAR pronounced. Amounts of other trends: varying, usually low.
MUSCULAR-FAT	MESO-ENDO	SOFT, ROUND predominant; BIG-BONED, MUSCULAR secondary. Amounts of other trends: usually low.
MUSCULAR-THIN	MESO-ECTO	DELICATE, LINEAR predominant; BIG-BONED, MUSCULAR secondary. Amounts of other trends: usually low.
PLUMP-DELICATE	ENDO-ECTO	DELICATE, LINEAR predominant; SOFT, ROUND secondary. Amounts of other trends: virtually lacking. OR DELICATE, LINEAR and SOFT, ROUND in about equal moderate amounts. Amounts of other trends: virtually lacking.
MODERATE MIXTURE	MODERATE MIXTURE	Approximate balance of components. Neither SOFT, ROUND; BIG-BONED, MUSCULAR; nor DELICATE, LINEAR extreme or uniformly prominent. Amounts of trends: no trend in more than moderate amount.

Women in various occupations were individually classified into one of these seven categories of body build. Some sociological background data were also collected from each subject.

Findings:

A. "There appear to be some distinct constitutional types of women who tend to engage in particular types of military activities according to the ... seven major types of body build distinguished in this study... ."

B. "Most occupational or other categories, although having MODERATE MIXTURES and THIN women as the leading types, show other distinct differences in trend when compared with each other. (As to sizing tariffs, it is important to realize that MODERATE MIXTURES, who show no extreme tendency in body build, tend to be below average in size.)

C. "Means of the seven body types vary for the 38 measurements and reflect the direction of the observational criteria for the seven body types.

D. "The seven body types show some differences in tendencies to disproportion, lumbar curve shape and placement of hip fat.

E. "Foot size and proportion tends to vary with body type. FAT women (relatively common in the Nurse group) tend to have comparatively small, plump feet which carry a heavy body weight."

The report is 122 pages long including one figure and 64 tables. There is no bibliography. The main data of the report are presented herein.

TABLE 46 - 2

Somatotype Distribution

Somatotype	WAC Officer (58)		WAC Enlisted (221)		Nurse (268)		Total Group (547)	
	No.	%	No.	%	No.	%	No.	%
Endo	3	3.2	31	14.0	43	16.0	77	14.1
Meso-Endo	2	3.4	36	16.3	23	8.6	61	11.2
Meso	7	12.1	15	6.8	16	6.0	38	7.0
Meso-Ecto	6	10.3	14	6.3	9	3.4	29	5.3
Ecto	16	27.6	49	22.2	58	21.6	123	22.5
Endo-Ecto	2	3.4	8	3.6	12	4.5	22	4.0
Moderate Mixture	22	37.9	68	30.8	107	39.9	197	36.0

TABLE 46 - 3

Army Women Compared with College Men and Women as to Incidence of Major Trend in Body Build*

Somatotype	College Men (Sheldon) 4000	College Men (Dupertuis) 1000	Women Students** (Sheldon) 2500	College Women 175	Army Women 547
Endo	13	13	25	17	25
Meso	26	26	15	13	7
Ecto	22	22	27	28	29
Moderate Mixture	39	39	33	42	39

* Bullen, Analysis of College Women, Fig. 2, page 50. ** Approximate estimates from silhouettes.

TABLE 46 - 4

Age Distribution

Types	WAC Officer						WAC Enlisted						Nurse						Total Group					
	35 and Under (47)		Over 35 (11)		Total (58)		35 and Under (188)		Over 35 (33)		Total (221)		35 and Under (231)		Over 35 (37)		Total (268)		35 and Under (466)		Over 35 (81)		Total (547)	
	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Endo	3	6.4	0	0.0	3	5.2	26	13.8	5	15.2	31	14.0	37	16.0	6	16.2	43	16.0	66	14.2	11	13.6	77	14.1
Meso-Endo	2	4.3	0	0.0	2	3.4	28	14.9	8	24.2	36	16.3	19	8.2	4	10.8	23	8.6	49	10.5	12	14.8	61	11.2
Meso	6	12.8	1	9.1	7	12.1	10	5.3	5	15.2	15	6.8	15	6.5	1	2.7	16	5.9	31	6.7	7	8.6	38	7.0
Meso-Ecto	4	8.5	2	18.2	6	10.3	12	6.4	2	6.1	14	6.3	6	2.6	3	8.1	9	3.4	22	4.7	7	8.6	29	5.3
Ecto	15	31.9	1	9.1	16	27.6	46	24.5	3	9.1	49	22.2	50	21.6	8	21.6	58	21.6	111	23.8	12	14.8	123	22.5
Endo-Ecto	1	2.1	1	9.1	2	3.4	7	3.7	1	3.0	8	3.6	7	3.0	5	13.5	12	4.5	15	3.2	7	8.6	22	4.0
Moderate Mixture	16	34.0	6	54.5	20	37.9	59	31.4	9	27.3	68	30.8	97	42.0	10	27.0	107	39.9	172	36.9	25	30.9	197	36.0

TABLE 46 - 5

Body Types of Women by Racial Group and For Four National Extractions

	Racial Groups				National Extractions			
Types	Mongoloid (2)	Negroid (27)	White (518)	Total Group (547)	Old American (272)	British (30)	Russian (19)	Balto-Ugric-Slav (25)
Endo	(50.0)	14.8	13.9	14.1	12.9	10.0	36.8	8.0
Meso-Endo	0.0	11.1	11.2	11.2	12.1	16.7	21.1	4.0
Meso	0.0	14.8	6.6	7.0	5.9	6.7	10.5	4.0
Meso-Ecto	0.0	0.0	5.6	5.3	5.5	10.0	0.0	12.0
Ecto	(50.0)	37.0	21.6	22.5	24.3	13.3	0.0	20.0
Endo-Ecto	0.0	0.0	4.2	4.0	5.1	6.7	0.0	4.0
Moderate Mixture	0.0	22.2	36.9	36.0	34.2	36.7	31.6	48.0

TABLE 46 - 6

Distribution and Statistical Values for Weight in 547 Army Women

Range lb.	Ecto No.	Endo-Ecto No.	Moderate Mixture No.	Meso-Ecto No.	Total No.	Meso No.	Endo No.	Meso-Endo No.
90- 94	1	-	-	1	2	-	-	-
95- 99	10	-	-	-	10	-	-	-
100-104	13	1	6	1	21	-	-	-
105-109	15	-	6	1	23	1	-	-
110-114	14	4	16	1	37	2	-	-
115-119	19	1	22	2	47	2	1	-
120-124	11	4	35	3	60	2	2	3
125-129	14	1	27	6	55	3	4	-
130-134	12	4	32	4	60	3	3	2
135-139	4	4	28	1	52	4	8	3
140-144	6	-	18	3	49	6	12	4
145-149	1	1	4	1	28	8	6	7
150-154	-	1	2	2	26	2	11	8
155-159	1	-	1	-	19	3	8	6
160-164	2	1	-	3	23	2	6	9
165-169	-	-	-	-	10	-	6	4
170-174	-	-	-	-	8	-	2	6
175-179	-	-	-	-	2	-	1	1
180-184	-	-	-	-	3	-	3	-
185-189	-	-	-	-	8	-	4	4
190-194	-	-	-	-	1	-	-	1
195-199	-	-	-	-	-	-	-	-
200-204	-	-	-	-	1	-	-	1
205-209	-	-	-	-	1	-	-	1
210-214	-	-	-	-	1	-	-	1
Mean	118.015	128.135	126.820	131.655	132.980	138.445	151.480	158.885
Mode	117.000	-	122.000	127.000	-	147.000	142.000	162.000
Median	117.235	130.000	127.500	129.585	131.540	141.665	151.135	157.915
Sigma	±14.415	±14.215	±11.090	±18.030	±19.950	±14.090	±16.525	±19.185
S.E.$_m$	± 1.300	± 3.031	± .790	± 3.348	± .853	± 2.286	± 1.883	± 2.456

TABLE 46 - 7

Comparison of Means for Army Photographic Series of 547 and Army Anthropometric Series of 8500*

	Total 8500 *	Total 547	Endo	Meso	Ecto
Stature					
Mean	162.365	162.075	160.623	163.974	164.049
Sigma	± 6.111	± 6.456	± 5.234	± 7.607	± 6.597
Breast Circumference					
Mean	89.104	89.444	95.325	89.868	84.008
Sigma	±7.683	±7.015	±5.383	±4.544	±4.767
Chest Circumference					
Mean	77.507	77.097	81.532	77.947	72.967
Sigma	±6.229	±5.910	±4.752	±2.791	±4.150
Waist Circumference					
Mean	67.321	69.344	74.974	70.316	64.780
Sigma	±6.596	±6.335	±4.202	±3.649	±4.066
Hip Circumference					
Mean	95.188	96.968	104.604	98.500	91.374
Sigma	±6.745	±6.848	± 5.712	±5.305	±5.066

* Tentative Pilot Means sent us by Dr. Francis Randall, Climatic Research Laboratory, subject to possible revision.

TABLE 46 - 8

Body Type Distribution of Means for Measurements Grouped by Body Regions

	Ecto	Endo-Ecto	Moderate Mixture	Meso-Ecto	Total	Meso	Endo	Meso-Endo
GENERAL								
Weight	118.015	128.135	126.820	131.655	132.980	138.445	151.480	158.885
$\frac{\text{Height}}{\sqrt[3]{\text{Weight}}}$ (Index of Linearity)	13.2	12.8	12.6	12.9	12.5	12.5	11.9	11.7
Stature	164.049	163.667	160.584	167.517	162.075	163.974	160.623	160.410
Cervicale Height	141.106	141.000	137.903	143.793	139.271	140.500	138.143	137.852
Sitting Height	83.901	83.409	80.897	86.655	83.475	84.132	82.592	83.033
Trunk Height	53.606	53.500	53.173	54.724	53.411	54.000	52.922	53.377
THORACIC TRUNK								
Chest Breadth	28.309	29.091	29.000	29.655	29.506	29.974	30.520	32.066
Chest Depth	18.393	18.864	18.746	19.138	19.209	19.737	20.065	21.082
Chest Circumference	72.967	74.773	75.383	76.793	77.097	77.947	81.532	85.787
Breast Circumference	84.008	88.318	87.665	88.000	89.444	89.868	95.325	99.557
ABDOMINAL TRUNK								
Waist Circumference	64.780	69.318	67.076	68.552	69.344	70.316	74.974	78.541
Waist Height	105.195	104.909	102.117	106.517	103.461	104.184	102.896	102.590
Trunk Depth	18.574	20.591	19.556	19.655	20.372	20.579	22.558	23.689
Bi-iliac	27.284	28.526	27.911	30.053	28.751	29.000	30.479	31.511
Hip Breadth	35.041	36.591	36.426	36.621	36.958	37.210	39.364	39.683
Hip Circumference	91.374	95.909	95.421	95.414	96.968	98.500	104.053	104.426
Hip Height	83.748	83.045	80.782	84.690	81.949	83.184	80.753	81.082
Buttock-Knee	56.780	58.091	56.133	57.793	57.126	57.526	58.610	58.230
ARMS, SHOULDERS, HANDS								
Biacromial	36.154	35.545	35.719	37.172	36.291	37.289	36.312	37.607
Acromion Height	134.984	135.682	131.726	137.655	133.119	134.053	131.844	131.803
Arm Length	71.894	70.545	69.502	72.793	70.355	71.290	69.237	69.590
Shoulder-Elbow	34.252	33.727	33.310	34.862	33.750	34.368	33.453	33.623
Forearm-Hand Length	43.431	43.045	42.563	44.138	42.974	43.737	42.481	42.951
Upper Arm Circumference	238.340	254.500	257.205	247.345	261.190	265.025	286.935	288.270
Forearm Circumference	218.910	222.000	229.400	226.655	231.440	236.475	242.265	252.665
Upper Arm Circumference	238.340	254.500	257.205	247.345	261.190	265.025	286.935	288.270
Bideltoid	39.447	39.500	39.919	41.103	40.490	41.395	41.169	43.082
Wrist Circumference	147.303	147.045	149.564	151.586	150.804	154.342	152.921	158.033
Hand Breadth	76.439	75.864	76.462	78.621	77.124	78.789	77.221	79.230
Hand Length	175.512	173.682	172.589	179.414	173.956	176.237	171.935	173.869
LEGS AND FEET								
Buttock-Knee	56.780	58.091	56.133	57.793	57.126	57.526	58.610	58.230
Patella Height	48.528	48.682	47.215	49.379	47.868	48.316	47.714	47.524
Foot Length	242.664	238.954	240.256	247.052	242.196	246.552	241.928	244.008
Foot Breadth	90.098	88.364	90.162	92.345	91.376	94.026	93.208	94.644
Heel Breadth	59.813	59.409	59.777	61.241	60.673	62.132	62.117	62.754
Ball Circumference	213.300	209.955	214.025	220.105	216.900	224.235	221.080	224.540
HEAD, FACE, NECK								
Head Height	124.361	125.091	123.306	125.552	125.077	127.842	126.104	125.738
Head Length	185.203	186.182	185.431	187.103	186.027	187.816	186.039	187.984
Head Breadth	144.065	144.591	145.574	146.069	145.684	146.605	146.714	147.623
Head Circumference	549.765	550.635	552.975	558.965	554.710	561.735	556.610	562.985
Neck Circumference	31.373	32.045	32.005	32.428	32.342	33.132	33.065	34.230

47. Churchill, Edmund and Gilbert S. Daniels. Nomographs of Head Measurements. Wright Air Development Center Technical Report 53-14, Wright-Patterson Air Force Base, Ohio, May 1953 (ASTIA No. AD-16748).

"To achieve the optimum design of equipment intended to fit the wearer's head closely, a knowledge of the interrelationships between the more important head dimensions is necessary. This report provides such information in the form of two nomographs for determining the most accurate estimate for each of twelve head dimensions based on known values of head length and head breadth, and head breadth and head circumference."

The two nomographs and selected additional data from the report have been reproduced and are included in this annotation.

"A statistical summary of the dimensions included in the nomograph is given in Table 47 - 1."

TABLE 47 - 1

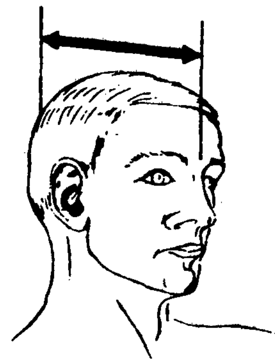
Means and Standard Deviations of Head Dimensions

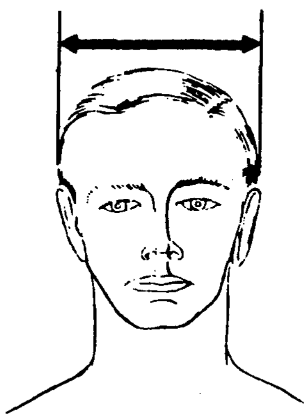
	Mean	Standard Deviation
Head Breadth	6.07 in.	.20 in.
Head Length	7.76 in.	.25 in.
Head Circumference	22.47 in.	.62 in.
Sagittal Arc	15.07 in.	.61 in.
Coronal Arc	13.83 in.	.51 in.
Bitragion-Minimum Frontal Arc	12.05 in.	.44 in.
Bitragion-Crinion Arc	13.10 in.	.53 in.
Posterior Arc	10.71 in.	.48 in.
Bitragion-Inion Arc	11.62 in.	.55 in.
Auricular Height	5.11 in.	.30 in.
Bitragion Diameter	5.60 in.	.21 in.
Wall to Tragion	4.03 in.	.30 in.
Minimum Frontal Arc	5.44 in.	.40 in.
Minimum Frontal Diameter	4.35 in.	.19 in.

The dimensions included in the nomograph are described as follows:

HEAD LENGTH

The maximum length of the head measured from glabella to the occipital region in the mid-saggital plane of the head with the spreading caliper.





HEAD BREADTH

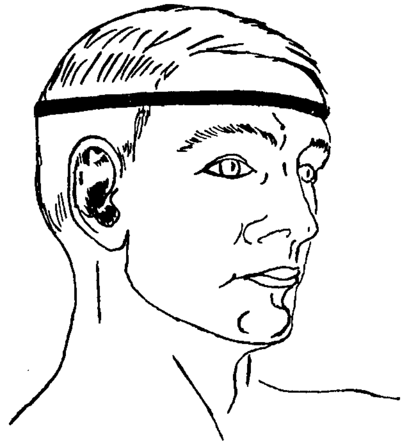
The maximum breadth of the head measured with the spreading caliper perpendicular to the mid-saggital plane of the head.

FIGURE 47 - 1

The Dimensions

HEAD CIRCUMFERENCE

The maximum circumference of the head measured with the tape passing over the brow ridges and held perpendicular to the mid-sagittal plane, but not necessarily horizontally.



SAGITTAL ARC

The arc measured with the tape in the mid-sagittal plane of the head, from glabella to the lowest point on the base of the skull that can be felt by a firm touch amid the nuchal musculature. This may be at inion or below.

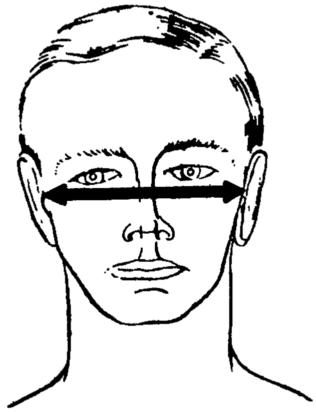
CORONAL ARC

The arc measured from right to left tragion over the top of the skull with the tape in a vertical plane. The subject sits looking straight ahead (the head in the Frankfort plane).

FIGURE 47 - 2

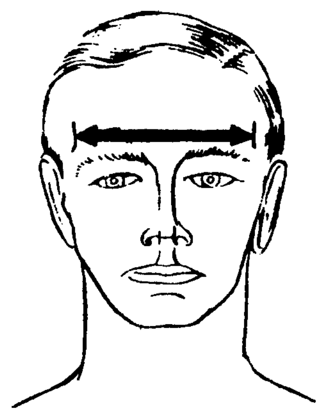
BITRAGION DIAMETER

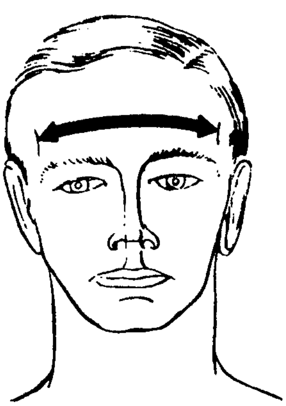
The diameter between right and left tragion measured with the light contact hand holding the spreading caliper in a horizontal plane.



MINIMUM FRONTAL DIAMETER

The minimum diameter meadured with the spreading caliper across the temporal crests at their point of greatest indentation. Care must be taken that the measurement is made on the crests and not over the temporal muscles.





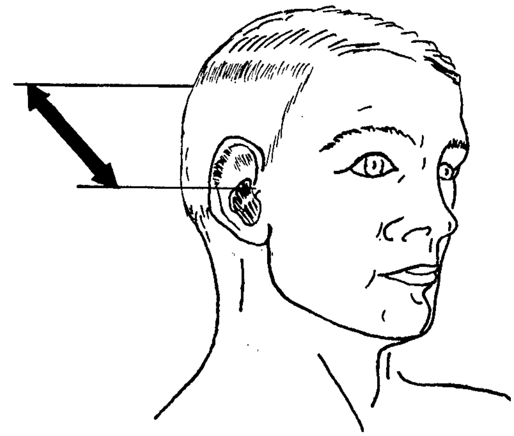
MINIMUM-FRONTAL ARC

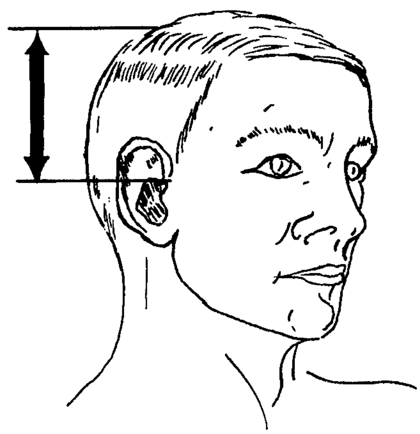
The arc measured across the forehead, above the brow ridges, with the tape passing across the crests of the temporal muscles at their points of greatest indentation toward the mid-sagittal plane of the head.

FIGURE 47 - 3

WALL TO TRAGION

With the back of the head pressed against the wall (head oriented in the Frankfort plane). The horizontal distance measured from the wall to the right tragion with the anthropometer.





HEAD HEIGHT

The vertical distance measured from tragion to the highest point of the skull with the anthropometer.

BITRAGION-CRINION ARC

The arc measured from right to left tragion with the tape passing over the mid-point of the hairline. If there is any appearance of balding in the subject, this measurement is omitted.

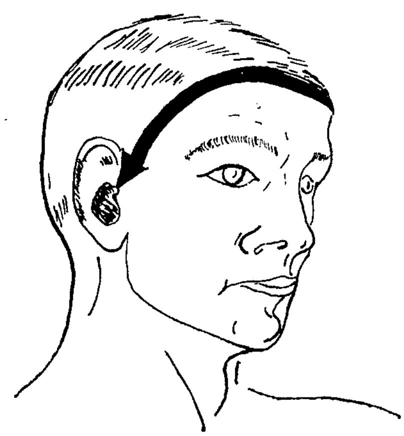
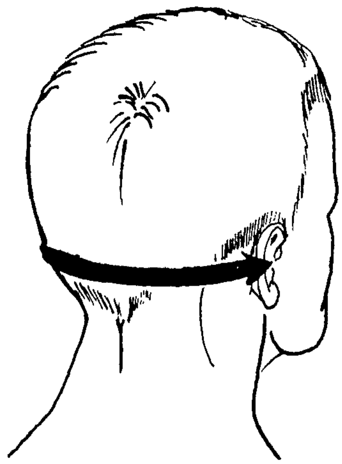


FIGURE 47 - 4

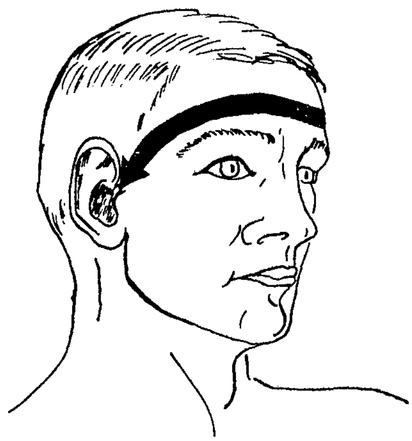


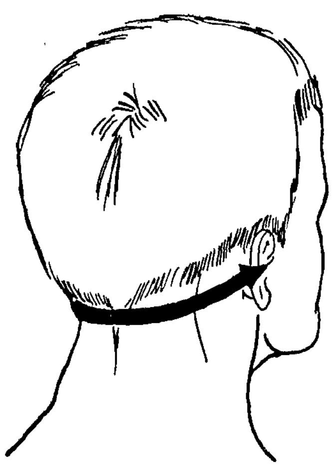
BITRAGION-INION ARC

The arc from right to left tragion measured with the tape passing over inion.

BITRAGION-MINIMUM FRONTAL ARC

The arc measured from right to left tragion with the tape over the region of the minimum frontal arc.





POSTERIOR ARC

The arc measured from right to left tragion with the tape passing over the lowest point of the skull where the nuchal musculature attaches.

FIGURE 47 - 5

A straight line, passing through known values of head length and head breadth, will also pass through average values for all other dimensions as shown. Each average value thus indicated is the mid-point of a range determined by adding and subtracting the amount shown below each line to the mid-point. This range will include about 67% of the men with the original given values of head length and head breadth.

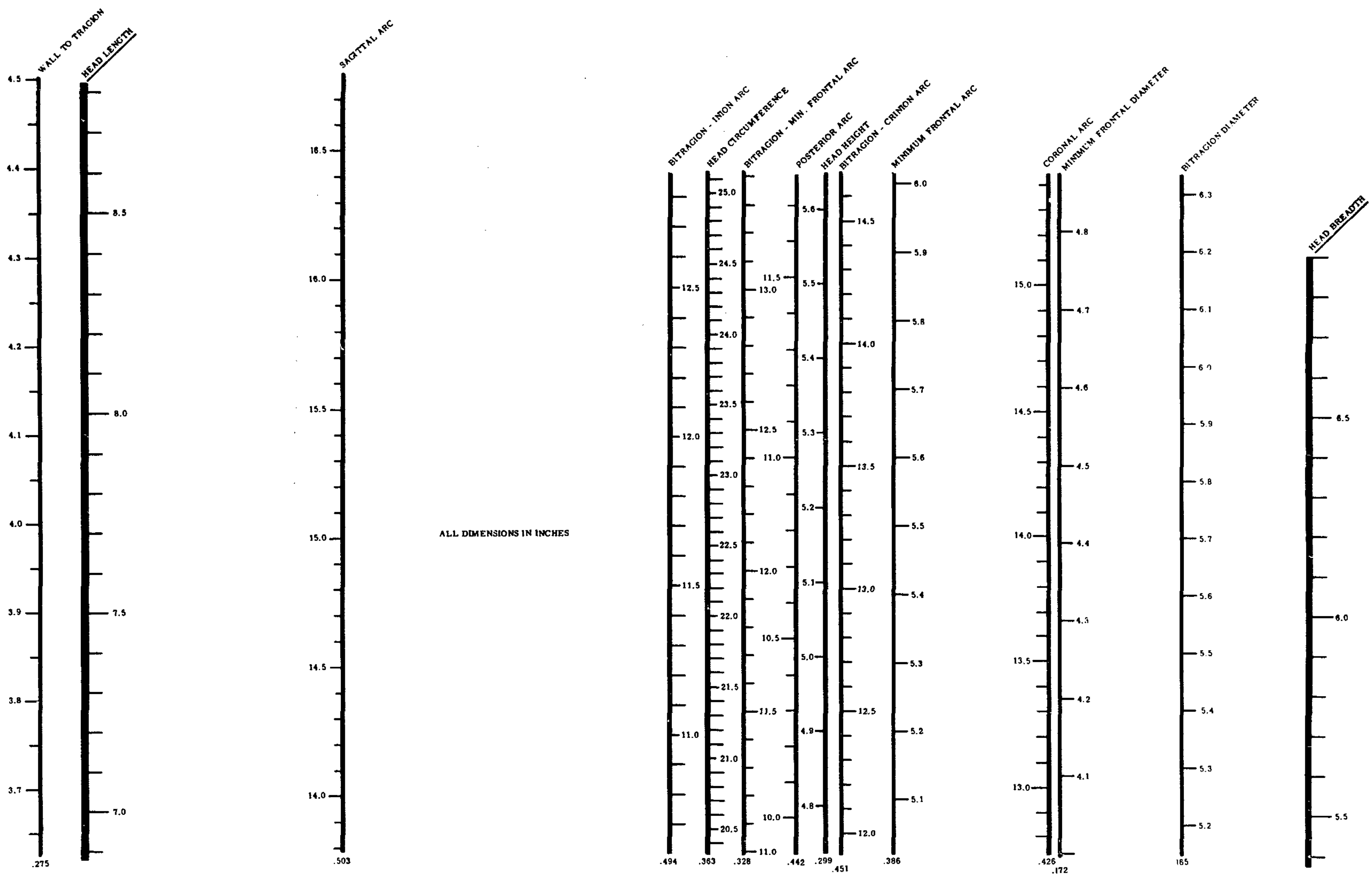


FIGURE 47 - 6

Nomograph of Head Dimensions Based on Head Breadth and Head Length

A straight line, passing through known values of head breadth and head circumference, will also pass through average values for all other dimensions as shown. Each average value thus indicated is the mid-point of a range determined by adding and subtracting the amount shown below each line to the mid-point. This range will include about 67% of men with the original given values of head breadth and head circumference.

Because of space limitations BITRAGION-INION ARC has been omitted from this nomograph. If this dimension is desired it can be found by the following formula:

(.157 x Head Breadth) + (.357 x Head Circumference) + 2.649
Standard error of estimate is .493

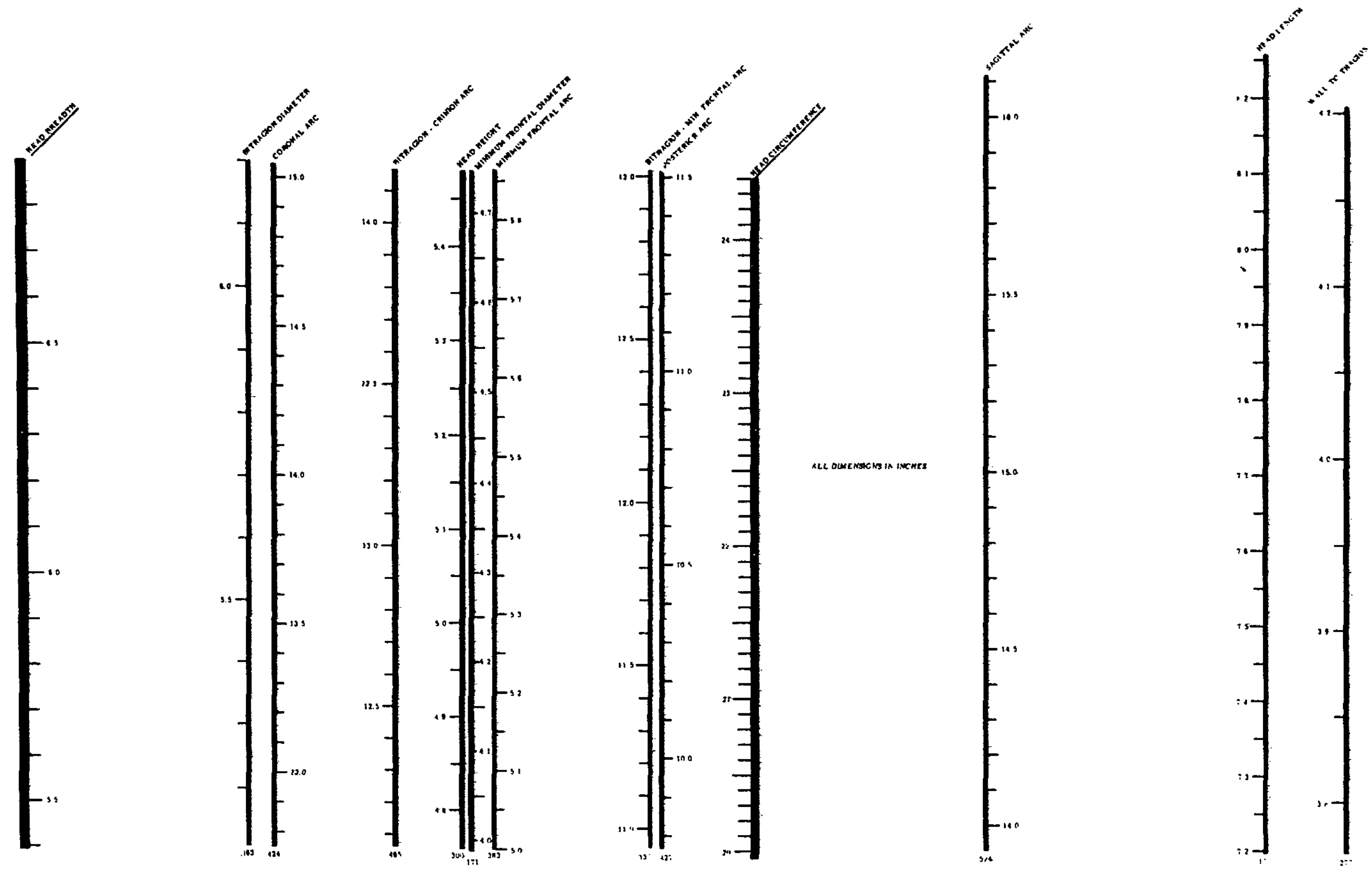


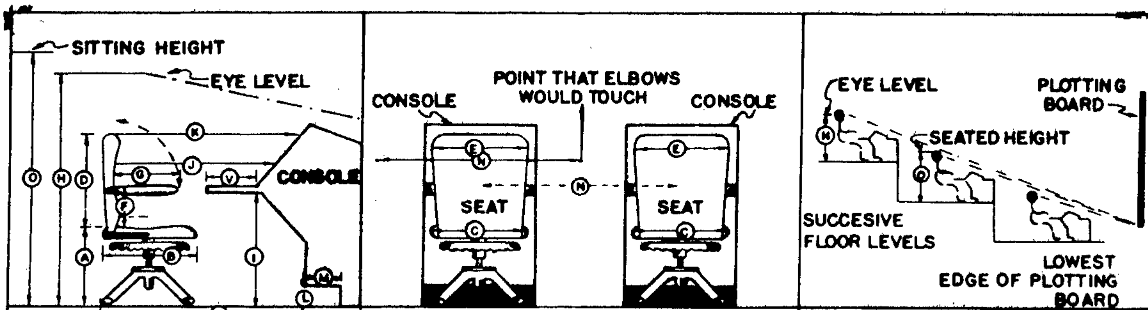
FIGURE 47 - 7

Nomograph of Head Dimensions Based on Head Breadth and Head Circumference

48. Coakley, John D., Joseph T. Fucigna, and Joseph E. Barmack (Dunlap and Associates, Inc.). A Functional Application of Anthropometric Data to the Design of the Workspace of PPI Scope Operators. WADC Technical Report 53-3, U.S.A.F., Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, January 1953. (Armed Services Technical Information Agency No. AD-6164.)

"The dimensions and layout of PPI consoles now in production are based on the needs of operators having average body dimensions. The use of average results in equipment unsuitable both for operators who are larger than average and for those smaller than average. Two needs assumed to be basic to the operations of a PPI scope operator are the need to see the GCI plotting board and the need to feel comfortable while operating the scope for long periods of time. With these needs as a basic consideration, compromise dimensions should be chosen to accommodate approximately the middle 95.5% of the military population. These principles are applied to the design of a PPI console and the operator's chair, and to the placement of the PPI scopes in a GCI station."

This report contains 15 pages and includes one table and three figures. The bibliography lists seven references. Two of the figures are presented in the annotation.

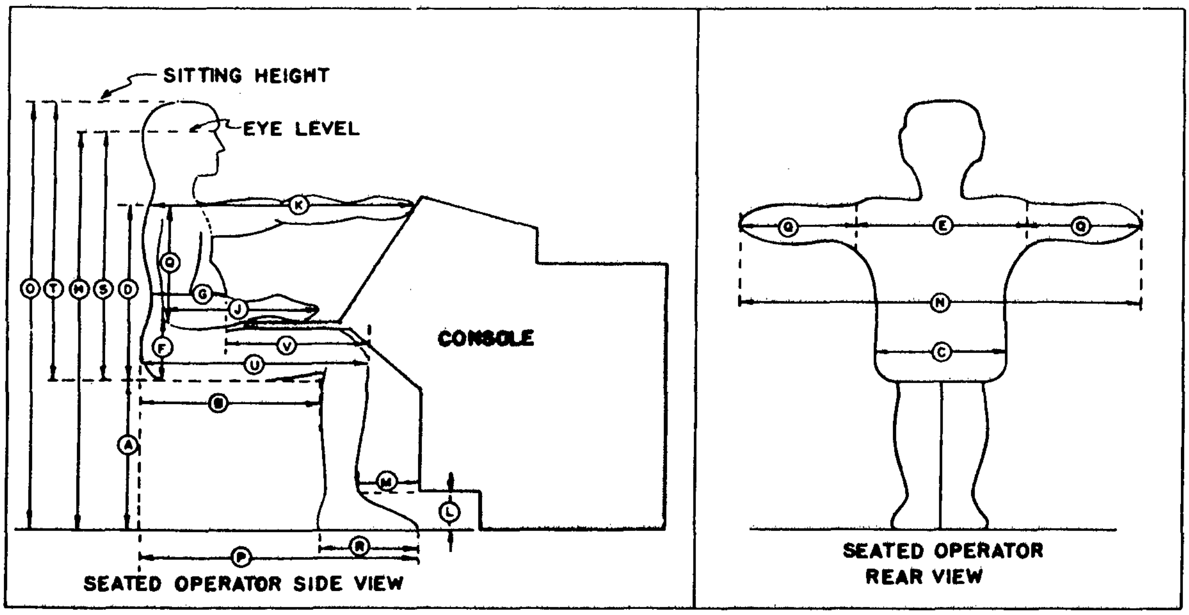


SIDE VIEW OF RECOMMENDED SEAT DESIGN WITH RESPECT TO THE P.P.I. CONSOLE	REAR VIEW OF RECOMMENDED SEAT DESIGN AND SPACING BETWEEN CONSOLES.	CRITICAL ITEMS FOR COMPUTING DROP IN SUCCESSIVE FLOOR LEVELS FOR MAXIMUM VISIBILITY OF PLOTTING BOARD BY ALL OPERATORS

Reference letter	Equipment dimension	Median or mean value (in inches) of corresponding anatomical dimension	Design value (in inches)	Remarks
A	Seat height	18 5	19 5	Seat height should be adjusted to ±2 5 inches from mean value. Adjusting wheel should have wide diameter so that adjustments may be made from seated position
B	Seat depth	19 0	21 0 max	back rest should be adjustable so that depth may be decreased five inches
C	Seat width	15.0	21 0 max	Four inches have been added to hip width to allow for comfortable separation of the legs
D	Back rest height	24 5	27 0 max	This value may be reduced to 23 inches because the upper four inches of the back do not require support
E	Back rest width	18 0	20 0 max	- - -
F	Elbow rest height	9.5	9 5	Variations about mean are not critical Elbow rest should pivot in the rear to permit the operator to enter and leave with ease.
G	Elbow rest depth	8 0	10 0	Elbow rest depth is determined by abdomen depth to permit closest proximity of body to scope
H	Eye level for computing maximum height of console	-	44 5 min	Maximum height of console depends on the size and position of the plotting board and the slope of the floor levels to the front In computing the visual clearance over the console the operator eye level should be that of the smallest operator
I	Writing table height	23.0	29 0 min *	This value should be minimum for clearance of knees Four inches are added to accommodate the thighs It does not include the allowance for the thickness of the table. It allows for footwear with a one inch elevation.
J	Minimum distance of lower bank of controls from back of seat	19.5	19.0 min.	This value cannot be less than 19.0 inches without making it difficult or impossible for the largest operators to manipulate these controls
K	Maximum distance of upper bank of controls from back of seat	35.0	26 0 max.	This value cannot be exceeded without causing the smallest operator to bend the body forward to reach for the upper controls
L	Minimum clearance for height of instep	-	5.0 min *	It is not necessary that the clearance extend completely across the width of the cabinet The front sides of the cabinet may reach the floor to provide support for the console.
M	Minimum clearance for length of forefoot	-	7.0 min	See note for L above
N	Distance between console centers which will allow unimpeded elbow movement	-	52.0 max.*	Compromises with this value will be necessary to crowded areas It is recommended that the minimum separation be not less than 26 inches to allow for passage of operators between chairs.
O	Height of seated operator for computing drop in successive floor levels to permit unobstructed view	-	61.0 max	Compromises with this value may be made at an increasing cost in obstruction of the view of the plotting board.
P	Total depth of work space exclusive of console and space behind chair	-	39.5	- - -
V	Depth of writing table	-	19.0 min.	This is the minimum distance to prevent bruising the knees of long-legged persons with thin torsos when they sit close to the table.

FIGURE 48 - 1

Recommended Dimensions, Based on Anthropometric Measurements, for the Design of Some Components of the PPI Operator's Workspace



Reference letter	Body dimension	Sex	Mean or Median in inches	Standard deviation (σ) in inches	Source of data	M ± 2σ	Step	Recommended design value in inches: Male & Female	Recommended design value in inches: Both sexes	Remarks
A	Seat height	M	19.0	.89	2	17.2 - 20.8	M + 1 in.	20	19.5	Seat height should be adjustable ± 2.0 inches from recommended values for either males or females and ± 2.5 inches from recommended value for both sexes. One inch is added to mean to allow for shoe heel height.
		F	18.1	.89	2	16.3 - 19.9		19		
B	Seat depth	M	18.9	.96	2	16.9 - 20.8	M ± 2σ	21	21	Back should be adjustable to decrease seat depth four inches for either male or female and five inches for combined male and female value.
		F	18.2	1.04	2	16.1 - 20.3		20		
C	Seat width	M	14.0	.74	1	12.5 - 15.5	M + 2σ	19.5	21	Four inches are added to allow for separation of the legs for comfort.
		F	15.0	1.03	1	12.9 - 17.1	+ 4 in.	21		
D	Top of shoulder to seat	M	23.8	.96	1	21.9 - 25.7	M + 2σ	26	27	- - - -
		F	24.6	1.19	5	22.2 - 27.0		27		
E	Shoulder width	M	18.0	.80	1	16.4 - 19.6	M + 2σ	20	20	- - - -
		F	16.1	.81	1	14.5 - 17.7		18		
F	Elbow to seat	M	9.6	.89	2	7.8 - 11.4	M	9.5	9.5	Mean value is recommended since the item is not critical.
		F	9.7	.89	2	7.9 - 11.5		9.5		
G	Abdominal depth	M	8.2	.64	1	6.9 - 9.5	M + 2σ	10	10	- - - -
		F	Not available							

FIGURE 48 - 2

Data and allowances utilized in arriving at the body dimensions recommended for use in designing the workspace of a PPI scope operator. These dimensions do not include allowances for clothes (except shoes).

Reference letter	Body dimension		Mean or Median in inches	Standard deviation (σ) in inches	Source of data	$M \pm 2\sigma$	Step	Recommended design value in inches: Male & Female	Recommended design value in inches: Both sexes	Remarks
H	Floor to eye level	M					Minimum	47.5	44.5	This value is computed by adding to S the seat level at its lowest adjustment.
		F					A + S	44.5		
I	Knee height	M	23.0	.96	1	21.1 - 24.9	$M + 2\sigma$	25	25	One inch is added to the mean to allow for shoe heel height.
		F	21.1	.81	1	19.5 - 22.7		23		
J	Elbow to fingertips	M	19.5	1.00	4, 1	17.5 - 21.5	$M + 2\sigma$	19	19	2.5 inches have been subtracted to allow for contraction when the thumb and fingers are placed tip to tip for use.
		F	Not available				- 2.5 in.			
K	Anterior arm reach	M	35.2	1.63	1	31.9 - 38.5	$M - 2\sigma$	29.5	26	Same as item J.
		F	31.1	1.36	1	28.4 - 33.8	- 2.5 in.	26		
L	Height of instep	M					Estimated	5	5	- - - -
		F								
M	Length of forefoot	M					Estimated	7	7	- - - -
		F								
N	Elbow to elbow	M					Items	52	52	Over-all width of workspace.
		F					2Q + E	48		
O	Floor to top of head	M					Maximum	61	61	Over-all height of workspace when seat is raised to a maximum and T is added to allow for visibility over heads of operators in front.
		F					A + T	57		
P	Toe to back of seat	M					Items	32.5	32.5	Over-all depth of workspace when there is no indentation in the console for the feet.
		F					B + R	30.5		
Q	Shoulder to elbow	M	14.7	.67	1	13.4 - 16.0	$M + 2\sigma$	16	16	- - - -
		F	13.7	.60	1	12.5 - 14.9		15		
R	Foot length	M	10.5	.45	1	9.6 - 11.4	$M + 2\sigma$	11.5	11.5	This measurement may also be used to determine the amount of clearance behind the chair.
		F	9.6	.40	1	8.8 - 10.4		10.5		
S	Eye level to seat	M	32.0	1.26	3	29.5 - 34.5	$M - 2\sigma$	29.5	27.5	Distance from head top to eye level was subtracted from head top to seat. The larger sigma was employed.
		F	29.8	1.26*	6	27.3 - 32.[illegible]		27.5		
T	Seat level to top of head	M	36.4	1.26	1	33.9 - 38.9	$M + 2\sigma$	39	39	- - - -
		F	34.1	1.02	1	32.1 - 36.1		36		
U	Buttock to knee	M	23.6	1.04	1	21.5 - 25.7	$M + 2\sigma$	26	26	- - - -
		F	22.6	.96	1	20.7 - 24.5		24.5		
V	Abdomen to knee	M					Items	19	19	- - - -
		F	Item G Not available				U-Minimum G			

*Variability for female not available; male variability was utilized.

FIGURE 48 - 2 (Continued)

49. Davenport, Charles B. Human Growth Curve. The Journal of General Physiology, Volume 10, No. 2, 20 November 1926, pp. 205-216.

This study was made because, "In view of the unsatisfactory condition of the analysis of the human growth curve it has seemed desirable to reattempt it, using the best available data."

"The curve of development of weight from conception to maturity is based on data drawn from various sources. For the antenatal portion the data of Streeter (year, 1920) have been utilized. For postnatal weights, up to 6 years, the data of Woodbury (year, 1921) have been used. For later years various sources, chiefly Nordic males as given in Table B of my Human Metamorphosis (year, 1926), were used. For annual increments in weight the same sources have been used, together with my Table D (year, 1926) for Nordic males."

In conclusion it was noted that:
"The human growth curve shows two (and only two) outstanding periods of accelerated growth--the circumnatal and the adolescent.

"The circumnatal growth cycle attains great velocity, which reaches a maximum at time of birth. The curve of this cycle is best fitted by a theoretical skew curve of Pearson's Type I. It has a theoretical range of 44 months and a standard deviation of 5.17 months. The modal velocity is 10.2 kilos per year.

"The adolescent growth cycle has less maximum velocity and greater range in time than the circumnatal cycle. The best fitting theoretical curve is a normal frequency curve ranging over about 10 years with a standard deviation of about 21 months and a modal velocity of 4.5 kilos per year.

"The two great growth accelerations are superimposed on a residual curve of growth which measures a substratum of growth out of which the accelerations arise. This probably extends from conception to 55 years, on the average. It is characterized by low velocity, averaging about 2 kilos per year from 2 to 12 years. It is interpreted as due to many growth operations coincident or closely blending in time.

"Our curve shows no third marked period of acceleration at between the 3rd and 6th years.

"The total growth in weight of the body is the sum of the weight of its constituent organs. In some cases these keep pace with the growth of the body as a whole; great accelerations of body growth are due to great accelerations in growth of the constituent organs. In other cases one of the organs of the body (like the thymus gland) may undergo a change in weight that is not in harmony with that of the body as a whole.

"The development of the weight in man is the resultant of many more or less elementary growth processes. These result in two special episodes of growth and numerous smaller, blending, growth operations.

"Hypotheses are suggested as to the basis of the special growth accelerations."

The article's 11 pages present no tables, 2 figures and 22 bibliographic references.

Additional references: Streeter, G.L. Weight, Sitting Height, Head Size, Foot Length and Menstrual Age of the Human Embryo. Carnegie Institution of Washington, Publication No. 275, Contributions to Embryology, 1920.

Woodbury, R.M. Statures and Weights of Children under Six Years of Age. Publication No. 87, Children's Bureau, U.S. Department of Labor, 1921.

Davenport, Charles B. Human Metamorphosis, American Journal of Physical Anthropology, Volume 9, 1926, p. 205.

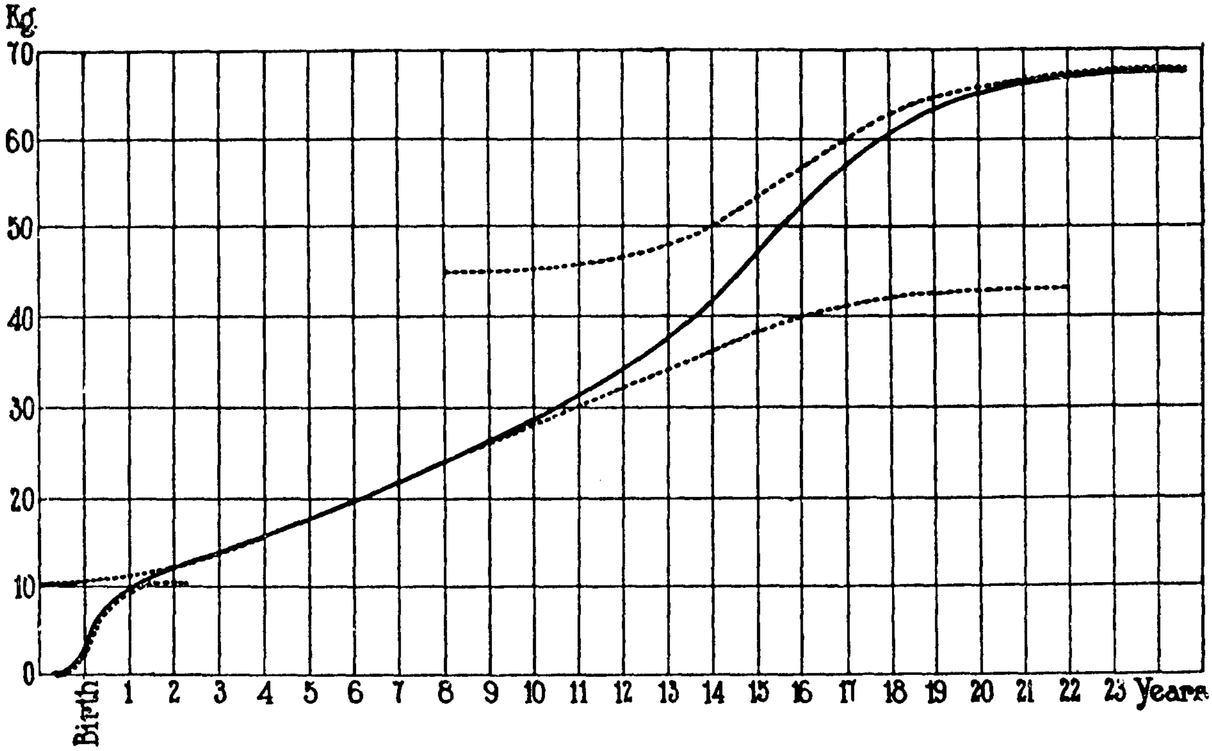


FIGURE 49 - 1

Analysis of the development curve of body weight (full line) into two auto-catalytic curves (dotted line at top and bottom) and a residual curve (dotted line in the middle). Human Nordic stock, males. The autocatalytic and residual curves drawn in free-hand. Abscissae, time in years; ordinates, body weight in kilos.

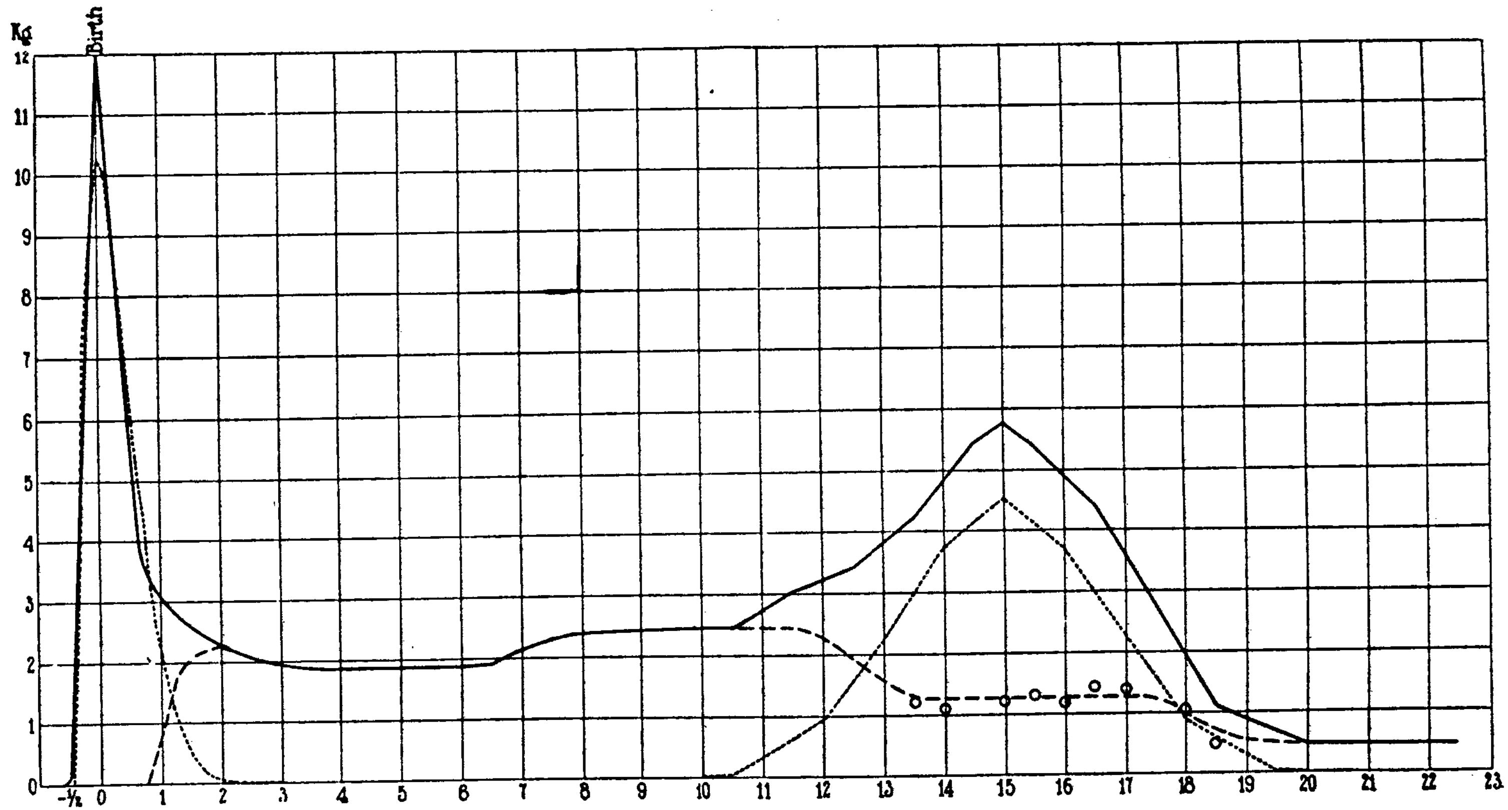


FIGURE 49 - 2

Full line, the curve of annual increment rate of total body weight, male Nordic stock (see text). Dotted line to left, theoretical skew curve corresponding to increments of circumnatal growth cycle. Dotted line to right, theoretical "normal" curve of increments corresponding to adolescent growth cycle. Dash line, 0.75 to 2.25 years, full line 2.25 to 10.5 years, dash line 10.5 to 20 years, and full line beyond 20 years indicates the residual growth increments. Abscissae, time in years; ordinates, annual rate of increments in weight in kilos. Small circles between 13 and 19 years indicate the precise points upon which is based the position of the dash line, which is smoothed between these years.

50. Dempsey, Charles A. Development of a Workspace Measuring Device. WADC Technical Report 53-53, U.S.A.F., Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, March 1953. (Armed Services Technical Information Agency No. 13206.)

"This Technical Report describes a Workspace Measuring Device which was developed to determine the maximum, minimum and optimum space requirements of Air Force Pilots when seated in the cockpit situation; and to simulate in the laboratory existing or proposed cockpit designs with an eye to proper space utilization."

"The wooden structure consists of ten horizontal arms mounted on a vertical rack and equipped with individual friction locking catches; and five vertical arms extending downward from an overhead beam and also fitted with friction locking catches. The locations of the vertical rack and the overhead horizontal beam with respect to the Seat Reference Point were determined from the body measurements of the United States Air Force 1950 Anthropometric Survey. Overhead beam elevation was obtained by adding 95% of the acromial sitting height to 95% of arm length. Location of the vertical rack was based on 95% of the arm measurement alone. Length of the 10 horizontal measuring rods was determined by 5% of the arm measurement; that of the 5 vertical ones on the sum of 5% of the acromial distance and 5% of the arm length. The horizontal arms are spaced 6 inches on center and numbered from -1 to +8 with the Zero arm located on a horizontal line passing through the Seat Reference Point. The vertical arms, also spaced 6 inches on center, are lettered from A through E with the B arm on a vertical line passing through the Seat Reference Point so that when the subject adjusts any sliding arm the actual vertical and horizontal distance from that point can be read directly from the scale on the side of the arm. The inner end of each arm is equipped with a 2 inch square cap which can be pivoted 45° above or below the arm centerline (Figure 50 - 1). Movement of this cap through the 90° arc by the subject provides data on the optimum angle for the end point of each vertical and horizontal arm with reference to the shoulder.

"Of the lift, push, pull, and rotate motions employed in various flying duties, the latter has proved to be the most difficult. Hence it was selected as the specific task which the subject was required to perform in each test. Therefore, a rotating knob which can be operated through a 360° range is mounted on the face of each pivoting cap.

"The seat and rudder pedals are attached to a platform which rotates around the Seat Reference Point in a horizontal plane and is calibrated in 15° increments up to 135° on each side of center.

"Figures 50 - 1 and 50 - 2 show a subject seated in the forward facing and 75° angled positions respectively. With the subject in the seated position and manipulating the Workspace Measuring Device through its complete range of operation, it is possible by plotting the 360 end points to define the most satisfactory arrangement of workspace for him. Thus, this device can provide detailed information on the size and shape of the space envelope available to the aircrewman in the seated position and with this information aircraft contractors can develop future cockpit mock-ups which will satisfy the spatial requirements for 90% of the Air Force population rather than the individual test pilot's desire."

This report is four pages long and contains three figures. Two bibliographic references are provided. A line drawing indicating the principle of the Workspace Measuring Device is presented.

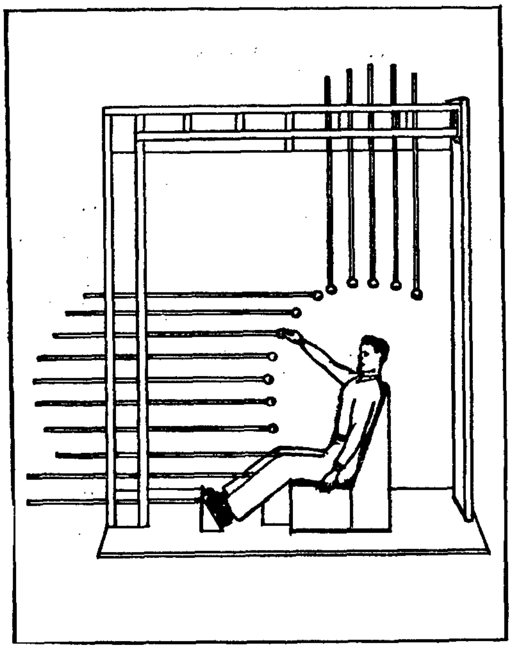


FIGURE 50 - 1
Forward Facing Position

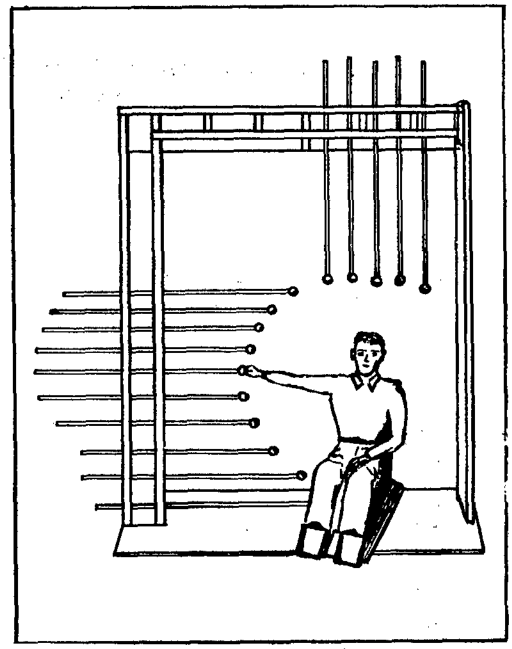


FIGURE 50 - 2
Seventy-Five Degree Angled Position

51. Dupertuis, C.W. and J.M. Tanner. The Pose of the Subject for Photogrammetric Anthropometry, with Especial Reference to Somatotyping. American Journal of Physical Anthropology, Vol. 8, N.S. No. 1, March 1950, pp. 27-47.

The reliability of the photogrammetric technique is considered to be high, with the largest error being due to the difficulty of posing a subject in precisely the same way on two occasions, or to the differences in posing technique of two investigators. A standard technique of posing is described in detail and is recommended for both photogrammetry and somatotyping. The present technique stems from the work of Sheldon and Hooton.

Standard positions for front, side and back views are given, following in general the method of Sheldon. A subordinate variant of the front view pose, with the arms fully supinated, is described for use on particular occasions. Illustrations are given of the correct pose in an adult and a 4 3/4-year-old child, and of the arm-supine pose.

There is a discussion of various points in connection with the techniques including the training of the person who poses the subject, which should include the actual measurement of a considerable number of pictures. For precise photogrammetry there should be horizontal and vertical 1 m and 1/2 m markers attached to the turntable exactly in the plane of the turntable center, and the heelplate-center distance should be specified: 10 cm is recommended for adults, 8 cm for children under 10. There is an appendix giving the figures for differences in various measurements when taken from this standard pose from a previously used "loose" pose.

The posing techniques are illustrated and elaborately described, therefore the original reference should be consulted for details. The article contains 20 pages, including three illustrations and a listing of three bibliographic references.

TABLE 51 - 1

Differences Between "Loose" and "Standard" Poses
56 Subjects

DIMENSION	MEAN DIFFERENCE LOOSE-STANDARD	MEAN DIFFERENCE IN PER CENT OF MEAN VALUE	STANDARD DEVIATION OF DIFFERENCE IN PER CENT OF MEAN VALUE	STANDARD DEVIATION OF DIFFERENCE IN PER CENT OF MEAN VALUE, FOR TWO LOOSE POSES; FROM TANNER AND WEINER
	mm			
FB_1	n.s.[1]		1.03	...
FB_2	n.s.		1.13	0.90
NTap	n.s.		1.97	0.73
NTt	n.s.		2.15	1.22
TT_1	+ 0.20	+ 0.75	1.88	1.64
TTnip	— 0.36	— 1.38	2.24	1.65
TT_2	n.s.		2.70	2.06
TT_3	n.s.		1.42	1.16
TB_1	+ 0.40	+ 0.97	3.09	1.76
TB_2	n.s.		1.60	0.30
TB_3	n.s.		0.76	0.69
ATU_0	— 0.21	— 1.57	2.77	1.93
ATL_1	+ 0.21	+ 2.03	4.75	3.93
ATL_3	n.s.		3.14	2.37
LTU_1	n.s.		1.35	1.55
LTU_2	n.s.		1.74	1.71
LTL_1	n.s.		0.86	0.97
LTL_2	n.s.		1.32	1.82

[1] n.s. = not significant at 5% level. Percentage mean differences associated with these n.s. values are all under ½%.

52. Etheredge, Maude L. and Leopold N. Judah. A Study of Age, Weight and Height of Entering Freshmen at the University of Illinois. Research Quarterly, Volume 11, No. 1, March 1940, pp. 142-3.

This study presents data "taken from the records of the University of Illinois Health Service and cover the compulsory entrance examination of students for the years indicated. An index number is computed for each yearly average figure. It will be seen that there has been some decrease in the age of the students entering the University of Illinois but not much change in weight and height. This shows that the Illinois students are participating to some degree in the national gain in weight and height."

No data on measuring methods was included in the article, but there was one table and four bibliographic references. The table of data is included in the annotation.

TABLE 52 - 1

Measurements of Entering Freshmen

MEN

Academic Year Exam.	Number Measured	Index	Average Age Yrs.	Index	Average Height (in.)	Index	Average Weight (lbs.)
1917–18	282	1.02	19.04	.999	68.14	1.01	142.37
1918–19	2050	1.01	18.88	.979	65.68	.968	136.74
1919–20	1624	1.04	19.47	.964	65.7	.948	133.8
1920–21	1239	1.013	18.95	1.0	68.2	.970	136.86
1921–22	1504	1.01	18.88	.971	65.19	.958	135.11
1922–23	1429	.994	18.58	.992	67.69	.970	136.92
1923–24	1366	1.01	18.9	1.002	68.42	.974	137.22
1924–25	1850	1.005	18.8	.999	68	1.002	141.4
1925–26	2075	1.00	18.71	.994	67.75	1.02	143.8
1926–27	2242	1.00	18.73	1.0	68.2	1.005	141.8
1927–28	1875	1.00	18.72	1.01	68.96	.998	140.7
1928–29	1894	.987	18.44	1.02	69.12	1.018	143.27
1929–30	2029	.997	18.63	1.01	68.85	1.00	141.6
1930–31	2281	.9875	18.46	.998	68	.995	140.2
1931–32	1785	.988	18.48	1.01	69	.990	139.15
1932–33	1421	.978	18.3	.996	67.9	.990	141.4
1933–34	1554	.987	18.44	1.015	69.2	.993	140
1934–35	1929	.990	18.50	1.016	69.24	1.02	143.72
1935–36	2184	.990	18.49	.989	67.42	1.017	143.21
1936–37	2486	.992	18.55	1.00	68.44	1.03	145.68

WOMEN

Academic Year Exam.	Number Measured	Index	Average Age Yrs.	Index	Average Height (in.)	Index	Average Weight (lbs.)
1919–20	521	1.056	19	.987	62.25	.993	117.3
1920–21	477	1.11	20	.999	63	1.06	125.4
1921–22	488	1	18	1.03	65.2	1.058	124.9
1922–23	535	1	18	.984	62	.982	116
1923–24	658	1	18	.973	61.4	.967	114.1
1924–25	654	1	18	.997	62.8	1.01	119.6
1925–26	818	1.017	18.3	1.01	63.6	1.00	118.2
1926–27	808	1	18	1.00	63.1	.985	116.5
1927–28	772	1.02	18.4	1.00	63.2	.998	117.9
1928–29	750	.995	17.9	1.01	63.9	1.008	119
1929–30	879	1.01	18.2	.989	62.4	1.00	118.1
1930–31	769	.995	17.9	1.01	63.9	.990	117
1931–32	724	.955	17.2	.973	61.4	.975	115.1
1932–33	545	1	18.0	1.01	63.6	1.02	120.6
1933–34	647	.984	17.7	.999	63.0	.994	117.3
1934–35	784	.984	17.7	.999	63.0	1	118.1
1935–36	785	.984	17.7	1.01	63.6	1.024	121
1936–37	867	.989	17.8	1.01	63.8	1.016	120

53. Gavan, James A. The Consistency of Anthropometric Measurements. American Journal of Physical Anthropology, New Series, Volume 8, 1950, pp. 417-426.

"This study is based on 62 measurements taken by 6 teams on 5 subjects. The average of the standard deviations and coefficients of variation for each measurement were used as measures of consistency, the differences in repeated measurements when the subject and technique remain constant. The measurements were divided into three consistency groups, high, medium and low, and the factors which brought about this division were analyzed.

"It was shown that as the size of the mean increases, the deviations about that mean can be expected to increase. The size of these deviations will be smallest when the position of the subject and instrument are the only factors involved. The deviations increase as the technician must pay more attention to the landmarks. The differences between those measurements in which both landmarks are determined by the instrument in the process of taking the measurement, and those in which only one easily located landmark is used, is negligible. The consistency decreases when the landmarks are independent of the measurement, when there is no objective method of placing the structure to be measured in a standard position, or when the technician must estimate the position of his instrument either because he cannot see both landmarks simultaneously or because the landmarks are not easily located in terms of body markings. The consistency further decreases when a very mobile structure is measured, when the position of the instrument is very indefinite, or when the landmarks are defined terms of other measurements.

"When only one technician is used, the consistency of all groups will increase, and consistency should more closely approximate that of the Davenport study (of this same problem) (Davenport, C.B., Steggerda, M., and Drager, W. Critical Examination of Physical Anthropology on the Living).

"No attempt has been made to define a good measurement. Its quality is determined by many things; primarily by the use which is made of it. A low consistency measurement would be good if it were the only one which would give data for the solution of any given problem. However, the interpretation of such data should be colored by the expected consistency of the measurements used."

Two tables, one figure and five bibliographic references are included.

TABLE 53 - 1

Measurements Arranged by Consistency Groups in Descending Order of the Average Means (M) and Giving the Average of the Standard Deviations (S), Average of the Coefficients of Variation (V), the Number of Times Each Measurement was Taken by all Teams, and the Number of Series Available. Stature has been Placed in a Group by Itself.

Measurement	No. cases	No. series	$\overline{M}$	$\overline{S}$	$\overline{V}$
HIGH CONSISTENCY					
Cervicale ht.	166	6	1504.3	10.2	0.7
Outseam	196	8	1077.5	9.4	0.9
Sitting ht.	195	8	912.6	5.9	0.6
Arm lgt.	196	8	786.8	6.7	0.8
Inseam	195	8	786.0	7.6	0.9
Buttock-knee	195	8	598.4	5.6	0.9
Patella ht.	180	7	562.6	5.4	1.0
Head circum.	197	8	524.2	3.4	0.6
Forearm-hand lgt.	150	5	474.2	3.8	0.8
Foot lgt.	194	8	264.7	2.7	1.0
Head lgt.	194	8	192.0	1.5	0.8
Head br.	193	8	158.1	1.4	0.9
Bizygomatic br.	196	8	142.6	2.0	1.4
Hand br.	186	6	83.0	1.8	2.2
Nose br.	194	8	35.3	1.3	3.8
Nasal root br.	196	8	12.7	1.2	9.2
LOW CONSISTENCY					
Waist circum.	195	8	816.2	17.7	2.2
Tot. crotch lgt.	175	6	730.0	22.8	3.1
Lower leg lgt.	148	5	465.1	11.6	2.5
Bi-elbow br.	138	4	444.7	11.1	2.5
Mid. thigh circum.	69	4	439.9	13.3	2.8
Arm scye	195	8	432.3	14.2	3.8
Cross back width	183	7	376.4	11.4	3.0
Up. leg circum.	69	4	349.7	9.2	2.6
Axillary arm circum.	70	4	308.7	8.8	2.9
Mid. forearm circum.	70	4	242.1	11.5	4.7
Shoulder lgt.	197	8	148.2	9.1	6.3
Stature	196	8	1755.1	5.1	0.3

Measurement	No. cases	No. series	$\overline{M}$	$\overline{S}$	$\overline{V}$
MEDIUM CONSISTENCY					
Hip circum.	194	8	951.5	10.4	1.1
Chest circum.	195	8	931.6	13.1	1.4
Sleeve lgt.	174	6	815.4	12.9	1.6
Trunk ht.	151	5	595.0	8.3	1.4
Crotch thigh circum.	70	4	586.5	8.0	1.4
Bideltoid	197	8	449.5	6.5	1.5
Lower thigh circum.	68	4	389.9	6.2	1.6
Shoulder-elbow lgt.	151	5	373.4	5.9	1.6
Neck circum.	195	8	370.3	6.2	1.7
Hip br.	140	4	368.0	5.4	1.5
Calf circum.	70	4	364.6	4.7	1.3
Upper arm lgt.	149	5	343.2	6.8	2.0
Bi-iliac dia.	147	5	294.0	7.7	2.6
Mid. up. arm circum.	70	4	288.4	6.7	2.4
Chest br.	151	5	282.7	5.4	1.9
Up. forearm circum.	70	4	268.3	4.0	1.5
Ankle circum.	187	7	256.1	6.3	2.5
Low. up. arm circum.	70	4	256.1	5.0	2.0
Trunk depth	150	5	239.7	6.7	2.8
Ball foot circum.	195	8	239.2	4.8	2.0
Chest depth	150	5	216.1	6.4	3.0
Hand lgt.	196	8	194.3	3.0	1.6
Instep lgt.	192	8	194.2	4.4	2.3
Wrist circum.	186	7	167.1	3.8	2.3
Head ht.	149	5	133.6	2.7	2.1
Face lgt.	184	7	123.2	2.8	2.3
Min. frontal dia.	193	8	111.3	3.0	2.7
Bigonial dia.	195	8	106.9	2.5	2.2
Foot br.	196	8	93.8	2.9	3.1
Biocular br.	183	6	92.1	2.4	2.7
O. C. S.[1]	184	6	85.8	2.7	3.2
Heel br.	195	8	66.5	2.6	3.8
Nose lgt.	193	8	57.9	2.5	4.8
Interocular br.	193	8	33.3	2.0	6.0

[1] Outer canthus-otobasion superior.

54. Gray, H. and F. Fraley. Growth Standards: Height, Chest-Girth and Weight for Private School Boys. American Journal of Diseases of Children, Volume 32, No. 4, October 1926, pp. 554-555.

The purpose of this study is noted by the authors: "Although for public school work the best standards are those published by Baldwin (Baldwin, B.T. The Use and and Abuse of Weight-Height-Age Tables as Indexes of Health and Nutrition), we believe that separate standards are necessary for judging the development of boarding and country day school boys; excluding (a) private schools in the city; (b) boys substandard to physical examination; (c) boys whose parents may be known to be of European stock; (d) body measured by observers or with apparatus whose accuracy was, on investigation, felt to be doubtful."

Two tables are included (1) height, chest and weight for age and (2) weight for height standard. These are based on a consolidation of the following groups: "380 boys in Groton, Middlesex and River's schools," "370 boys in the Protestant Episcopal Academy," and "266 boys in the Hill School." Four bibliographic references are listed.

55. Harvard University, Department of Anthropology. Measurements of Body Build in a Sample of the United States Army. Office of the Quartermaster General, Research and Development Contract W44-109-qm-2014, October 1949.

Purpose: "The present report deals with the more important measurements gathered on indivdual soldiers during the course of the survey (Hooton, Earnest A., Frederick R. Wulsin, Francis R. Randall, James M. Andrews, Frederick L. Stagg, Carl C. Seltzer, Natalie Bill, and Kathleen G. Hall. Body Build in Relation to Military Function in a Sample of the United States Army), as such measurements apply to the various body types, previously determined from the photographs.

"Dr. Francis Randall's extensive work on the metric data deals with separate measurements and combinations of measurements, but is not correlated with the individual body types as studied in this section of the survey. Consequently, this report analyzes some of the more important measurements showing the extent to which they change with shifts of the three structural bodily components in the many body types recognized. It further takes each body type large enough for analysis and compares it as a metric entity with certain other adjacent or morphologically similar types. It discusses also the detailed distribution of body groups and types in relation to stature and chest girth (which are the most important bivariates, according to Dr. Randall's studies for the setting up of equipment tariffs). Thus the report of this year supplements and completes that of the preceding year in giving the precise metric descriptions of the body builds which had been summarily classified and related to various facts of military or sociological interest.

"The principal practical applications of the results of the present report will be as follows: (1) to provide the Quartermaster Corps and its anthropological staff with an accurate idea not only of the numbers and percentages and origins of various body build types to be found in the Army, but also with arithmetic means of measurements and other statistical constants of such types, which will make possible the drawing up of schedules showing, e.g., how many 434's are to be expected and what sizes of equipment are required for them, and the same for every other body type; (2) to objectify the rather difficult morphological classifications of body types so that Army selectional personnel can easily make more effective assignments on the basis of height, weight, chest girth, and a few other measurements without expert guidance and without individual analyses of photographs by trained anthropologists. This phase of the study is treated only in a preliminary way in this report. It is hoped that the next year's report may present a complete method of body typing based upon the use of a few simple measurements and indices, without photographic assistance. The work on this problem is nearly complete."

Sample: The sample of United States Army soldiers is constituted as follows:

Whites, N = 39,376
Negroes, N = "more than 3,000"
Others, N = "scatterings"
Total, N = 45,000

Treatment: "This report deals only with the anthropometry of the White and Negro series, and considers the following principal records and measurements taken by Dr. Randall's staff on each individual: Age, Weight, Stature, Torso Length, Cervical Height, Chest Girth, Waist Girth, Hip Circumference. These have been selected from an array of more than 60 measurements taken on each individual by Dr. Randall's staff.

"The statistical constants determined for each of the measurements are range, mean, standard deviation, standard error, and coefficient of variation. No further statistical elaboration has been possible under the funds allotted to the contract. Actually, straightforward and simple arithmetical and percental methods of dealing with such data are usually quite sufficient for the derivation of all essential principles and conclusions. A good deal of statistical elaboration is often 'window dressing.'"

General Results (White subjects):

Distribution of Somatotypes (Body Types)

"In 39,376 White soldiers there occur 125 distinct body types of which 27 are excessively rare. Analyses of the occurrence of the various grades of the three structural components (each rated 1 to 7) shows that grade 1 in the third component (the least degree of elongation and attenuation) regularly goes with high values of the 1st (fatty component -7--'s, 6--'s, 5--'s). There are very few weak fat men in the Army series (high in the 1st component and low in the 2nd, bone-and-muscle, component). The percental expectation of the grade of each component in association with variations of the other two components makes it possible to predict with fair accuracy from the height/cube root of weight index the distribution of body types in any sample of U.S. White males of military age, and perhaps of other males of European ancestry.

"In general, very thin and very fat body types are rare in the Army. Balanced types (the three structural components equal or nearly so) tend to predominate.

Analyses of Separate Measurements

Age
"Mean age rises with increments of the 2nd (bone-and-muscle) component, falls with increments of the 3rd (elongation and attenuation) component, but does not increase or decrease regularly with rise of the 1st (fatty) component. Muscle increases after maturity, fat in some body types, but not all.

Weight
"Increases in progressively larger amounts with increments of the 1st (fatty) component; merely fluctuates with rise of the 2nd (bone-and-muscle) component; diminishes with rise of the 3rd (elongation and attenuation) component. The largest number of body types occurs in the average weight limits of 150-159.9 lbs.

Stature
"Stature rises with increase of the 1st (fatty) component; does not change consistently with increase of the 2nd component; increases largely with rise of the 3rd component. With increasing categories of stature, physically poor and mediocre types become more numerous. Short men have the best muscled physiques.

Torso Length
"Rises with 1st component increments; does not change with 2nd component; increases consistently with rise of 3rd component.

Bideltoid (Shoulder Breadth)
"Shoulder breadth rises with increase of 1st component; does not change regularly with 2nd component variations, but tends to increase if anything; drops slightly with rise of the 3rd component.

Chest Breadth
"Rises with 1st component increments; rises not as markedly with 2nd component. Diminishes only insignificantly with rise of the 3rd component.

Chest Depth
Increases with 1st component. Unreliable measurement.

Bi-iliac (Pelvic Breadth)
"Very stable, rises only with fat increases.

Leg Length
"Increases with rising 1st component, decreases with 2nd; increases with 3rd. The shortest legs are found in the strongest man.

Arm Length
"Behaves with structural changes much as does leg length.

Cervicals
"Shows changes similar to those of stature.

Chest Girth
"Rises with 1st component: increases irregularly with rise of 2nd; decreases with rising 3rd component.

Waist Girth
"Rises largely with 1st component increases; diminishes slightly with 2nd component increases; drops consistently with 3rd component increase.

Hip Circumference
"Rises with 1st component; fluctuates with 2nd; diminishes irregularly with 3rd.

Conclusion

"Changes in measurements of body types with increase of the grade of one of the three structural components, the other two being held constant, tend to be consistent in one or other direction when the 1st component (fatty deposits) and the 3rd component (elongation and attenuation) are concerned. Changes in the second component do not usually carry with them constant increases or decreases of measurements. Muscular relief and development is not as easily distinguishable from measurements as are fatty developments and elongation and attenuation."

General Results (Negro Subjects):

Analysis of Measurements

Age
"As in Whites usually rises with increments of 2nd component. Most Negro body types tend to have slightly younger mean age than corresponding types of Whites.

Weight
"Increments with change of component grades similar to those of Whites. Negroes, body type for body type, are from 1.7 to 7.7 lbs heavier than Whites (20 of 21 pairings).

Stature
"Negroes seem usually to exceed Whites of the same body types, but this comparison is hampered by paucity of high 1st component types among the former.

Torso Length
"Although taller than Whites, Negroes have consistently shorter torsos - type for type.

Bideltoid
"Negroes ordinarily have slightly wider shoulders than Whites.

Chest Breadth
"The measurement shows little relationship to shifting structural components. There is a tendency for Negroes to have slightly narrower chests than Whites of corresponding body builds.

Chest Depth
"No consistent difference between Negroes and Whites is apparent.

Bi-Iliac
"Rises in Negroes with increasing 1st component. No certain difference between Negroes and Whites.

Leg Length
"Increments with change of components are as in Whites. Type for type Negroes have much longer legs than Whites.

Arm Length
"Negroes also greatly exceed corresponding types of Whites in arm Length.

Cervicals
"Negroes consistently exceed Whites.

Chest Girth
"Chest girths of Negroes are almost invariable smaller (on the average) than those of Whites of corresponding body types.

Waist Girth
"Not much difference between Negroes and Whites.

Hip Circumference
"There is an uncertain tendency for Negroes to fall slightly below Whites in this measurement.

RÉSUMÉ OF MAIN POINTS IN MEASUREMENTS

"This Negro series is usually younger than the Whites when corresponding body types are compared. The Negroes are ordinarily heavier, taller, with shorter trunks, much longer legs and arms, slightly wider shoulders, slightly narrower and probably relatively but not absolutely deeper chests, smaller chest girths. These racial differences are consistent.

The Body Build Groups

"In general, on account of the small Negro series, many body types found in Whites are absent or insufficiently represented. Other body types occur in very different proportions among the Negroes. Notably, the latter tend to include far more of the tall slender types, far fewer of the plump and obese and short types. Details of comparisons are found in the text.

"In general, between Negroes and Whites of corresponding body types, the racial differences above explained are regularly in evidence."

This report is 304 pages long and is liberally saturated with statistical tables. There is no bibligraphy. Selected data from the report are presented in this annotation.

TABLE 55 - 1

Distribution of Somatotypes in the Total Series

		No.	Type	%
I	Thin, non-muscular, elongate (Others: 115,116,117,123-127, 134-137,214-217,221-227)	367	225	1.16
		341	226	1.08
		223	others	.70
		931	Total	2.94
II	Thin, sub-medium musculature, elongate	64	234	.20
		427	235	1.35
		227	236	.72
		718	Total	2.27
III	Thin, medium musculature (Others: 242-246, 244)	132	245	.42
		88	others	.28
		220	Total	.69
IV	Sub-medium, non-muscular, medium and elongate (Others: 314-317)	380	324	1.20
		1054	325	3.33
		194	326	.61
		97	others	.31
		1725	Total	5.45
V	Sub-medium, sub-medium musculature (Others: 331-337)	2038	334	6.44
		2321	335	7.33
		169	336	.53
		127	others	.40
		4655	Total	14.70
VI	Sub-medium, medium musculature	142	343	.45
		1371	344	4.33
		660	345	2.08
		2173	Total	6.86
VII	Sub-medium, muscular (Others: 253-256, 355, 362-364)	157	353	.50
		431	354	1.36
		164	others	.52
		752	Total	2.38
VIII	Medium plump, non-muscular (Others: 413-417,423)	560	424	1.77
		214	425	.68
		193	others	.61
		967	Total	3.05
IX	Medium plump, sub-medium musculature (Others: 431,432,436,437)	1481	433	4.68
		3347	434	10.57
		717	435	2.26
		60	others	.19
		5605	Total	17.70
X	Balanced, short to medium	100	442	.32
		2004	443	6.33
		3125	444	9.87
		5229	Total	16.52
XI	Balanced, tall	257	445	.31
XII	Medium fat, muscular (Others: 452,462)	1020	453	3.22
		457	454	1.44
		120	463	.38
		159	others	.50
		1756	Total	5.55

TABLE 55 - 1 (Continued)

		No.	Type	%
XIII	Fat, non-musc. and sub-med. musculature (Others: 523,524)	307	532	.97
		1252	533	3.95
		291	534	.92
		228	others	.72
		2078	Total	6.56
XIV	Fat, med. musculature	753	542	2.38
		1552	543	4.90
		160	544	.51
		2465	Total	7.79
XV	Fat, muscular (Others: 561-563)	307	552	.97
		213	553	.67
		48	others	.15
		568	Total	1.79
XVI	Very fat, non-musc., sub-med. musculature (Others: 621-625,631-731)	301	632	.95
		118	633	.37
		144	others	.45
		563	Total	1.78
XVII	Very fat, med. musculature (Others: 643,741)	185	641	.58
		522	642	1.65
		133	others	.42
		940	Total	2.65
XVIII	Very fat, very muscular	77	651	.24
		79	652	.25
		156	Total	.49

TABLE 55 - 2

Distribution of Stature Groups in the Total Series

Stature (cm)	No.	% of Total Series
150 - 154	35	.09
155 - 159	429	1.09
160 - 164	2581	6.56
165 - 169	7611	19.33
170 - 174	12094	30.72
175 - 179	10202	25.92
180 - 184	4819	12.24
185 - 189	1356	3.44
190 - 194	213	.54
195 - 199	27	.07
Totals	39367	100.00

56. Hooton, Earnest A., Frederick R. Wulsin, Francis E. Randall, James M. Andrews, Frederick L. Stagg, Carl C. Seltzer, Natalie Bill, and Kathleen G. Hall. Body Build in Relation to Military Function in a Sample of the United States Army. Office of the Quartermaster General, Research and Development Contract W44-109-qm-1078, Harvard University, Department of Anthropology, September 1948.*

Purpose: The purpose of the present report is to describe the somatotype composition of a series of United States soldiers and to determine whether there are distinct constitutional types of military personnel who engage in particular military activities. Certain sociological correlates of body type were also examined.

Subjects: N(Whites) = 31,658
N(Negroes) = 3,051

This sample represents men accepted for military service; not the total male population of military age. "Since the series was measured in the spring of 1946 and includes 85.53 per cent of men who have served 24 months or less, it is clear that it hardly represents, as a whole, seasoned combat veterans."

Classification of Body Types: "Body type classification is based upon the study of front, back, and side views of the nude individual, together with data on the relation of height to weight. Three structural body components are considered in the classification: fat development, muscle development, degree of attenuation or elongation as expressed by the index of height/cube root of weight. Each component is graded on a scale from 1 to 7, by morphological examination in the case of fat and muscle, by dividing the total range of the height/cube root of weight index into seven equal steps in the case of the third component which grades attenuation. The total body type of the individual is thus expressed by a three-digit combination, each digit ranging from 1 to 7. Thus 1-1-7 indicates a body type of minimum fat development, minimum muscle development, maximum attenuation, or height relative to weight. 4-4-4 indicates an individual at approximately the middle of the range of fat, muscle, and attenuation. These types, numerically designated, are lumped into 18 groups, each containing closely similar types, for purposes of correlation with military specialty and with other sociological phenomena." This somatotyping is a modification of the Sheldonian system.

Material - The Series: "The series includes approximately 50,000 photographs (front, side, and back views of each nude subject) with some 65 measurements of each individual. Photographs and measurements were taken under the direction of Dr. Francis R. Randall, Climatic Research Laboratory, Q.M.C., Lawrence, Mass."

Results:
White series: "...The whole series consists of 35.29 per cent of thin and sub-medium fat men, 43.63 per cent of medium plumpness or fleshiness, and 21.06 per cent of fat or very fat men. On the whole, then, the veteran series is skewed toward slimness, partly because of the low age of the majority measured.

"A breakdown on the basis of muscularity shows 12.61 per cent of relatively non-muscular types, 41.84 per cent of sub-medium muscularity, 35.32 per cent of medium musculature, and 10.21 per cent of pronounced muscularity.

"Of the 12.61 per cent classified as non-muscular, 1.17 per cent is composed of fat or very fat men, whose musculature may be a little better than is apparent from the photographs.

"Men of sub-medium muscularity (for this series) include thin men of sub-medium musculature and sub-medium fat men (below average fleshiness), as well as medium plump men of sub-medium muscularity. It is not believed that sub-medium muscular development in this series implies in itself functional inferiority or has any military significance. The first two classes just mentioned are slender men who are at least as muscular as they are fat. The medium plump, sub-medium musculature is the largest body group in the series and consists of men whose muscular development can probably be brought up to par by training.

* Editor's Note: The Laboratory moved to Natick, Massachusetts, in 1953.

"The two groups of 'medium' and 'pronounced' muscularity combine together 45.53 per cent. Actually these are all physically superior men from the point of view of any male distribution except this selected Army sample."

Physical differences are found between various occupational groups. Different educational and marital status groupings differ in somatotype.

Negro series: "The series of 3051 Negroes and Negroids consists of men who are characteristically thinner and more lightly muscled than Whites, except that shoulder musculature in Negroes tends to be heavier and trunk musculature somewhat sharper in definition. But Negroes are of more slender skeletal framework and their extremities are attenuated, and, in the case of the inferior extremity, the lower leg is extremely meager. Their total body types are then different from Whites with the same body build formulae. The modal body build in Negroes is sub-medium fat, sub-medium musculature (27.86%), a class which ranks only third in Whites and is especially common in the leaner, more elongate sub-adults."

Differences of body type among various occupational categories are established. Education and marital status are other variables reflecting differences in somatotype.

This report is 216 pages long and contains 139 tables but no figures. There is no bibliography. Selected data are included.

TABLE 56 - 1

Summary of Body Types According to Presumed Capacity for Physical Duties

	Percentage in Total White Series	
HEAVY DUTY (Requiring maximum strength and endurance)		
Balanced, short to medium	16.52	
Medium fat, muscular	5.55	
Fat, muscular	1.79	
Sub-medium, muscular	2.38	
Very fat, very muscular	.49	
		Total 26.75
MEDIUM DUTY (Requiring average strength and endurance)		
Sub-medium, sub-medium musculature	14.70	
Medium plump, sub-medium musculature	17.70	
Balanced, tall	.81	
Sub-medium, medium musculature	6.86	
Fat, medium musculature	7.79	
Very fat, medium musculature	2.65	
		Total 50.51
LIGHT DUTY (Requiring fair endurance, no great physical strength)		
Thin, sub-medium musculature, elongate	2.27	
Thin, medium musculature	.69	
		Total 2.96

TABLE 56 - 1 (Continued)

	Percentage in Total White Series	
MINIMUM DUTY (Requiring no physical exertion)		
Thin, non-muscular, elongate	2.94	
Sub-medium, non-muscular	5.45	
Medium plump, non-muscular	3.05	
Fat, non-muscular and sub-medium	6.56	
Very fat, non-muscular and sub-medium	1.78	
		Total 19.78

TABLE 56 - 2

Summary of Body Types According to Presumed Fitness for Military Functions

	Percentage of White Series	
COMBAT TYPES		
Thin (Air Force, flight; Gunnery, Intelligence, Reconnaissance, Communications; Medical stretcher-bearers)		
Thin, sub-medium musculature, elongate	2.27	
Thin, medium musculature	.69	
		2.96
Sub-medium (Air Force, flight; Combat Infantry, Gunnery, etc.)		
Sub-medium, sub-medium musculature	14.70	
Sub-medium, medium musculature	6.86	
Sub-medium, muscular	2.38	
		23.94
Medium (Combat Infantry, Gunnery, Combat Engineering, all combat duty)		
Balanced, short to medium	16.52	
Medium fat, muscular	5.55	
		22.07
Fat and Very Fat (Combat Engineering, Gunnery)		
Fat, muscular	1.79	
Very fat, very muscular	.49	
		2.28
	Total	51.25
GENERAL UTILITY TYPES (Combat or Service)		
Medium		
Medium plump, sub-medium musculature	17.70	
Balanced, tall	.81	
	Total	18.51

TABLE 56 - 2 (Continued)

	Percentage of White Series	
SERVICE TYPES		
Thin (Administration, Technical)		
Thin, non-muscular, elongate	2.94	
Sub-medium (Administration, Medical, Supply)		
Sub-medium, non-muscular	5.45	
Medium (As above, also Maintenance, Transportation, Construction)		
Medium plump, non-muscular	3.05	
Fat and Very Fat		
Fat, medium musculature (Maintenance, Transportation, Construction)	7.79	
Fat, non-muscular (Supply, Medical, Administration)	6.56	
Very fat, non-muscular (Supply, Medical, Administration)	1.78	
Very fat, Medium musculature (Engineering, Construction, Maintenance, etc.)	2.65	
	Total	30.22

TABLE 56 - 3

Rank and Percent of Groups According to
Frequency in Total Series - Military Unit AAF

	Flight	Ground & Others	Total AAF	Total Series
Med. plump, sub-med. musculature	15.62	16.09	16.01	17.72
Balanced, short to medium	15.77	14.94	15.07	16.56
Sub-med., sub-med. musculature	14.16	16.65	16.25	14.72
Fat, med. musculature	6.28	7.44	7.26	7.80
Sub-med., med. musculature	7.15	6.24	6.39	6.80
Fat, non-musc., sub-med. musc.	5.99	6.02	6.01	6.57
Med. fat, muscular	6.42	4.64	4.93	5.55
Sub-med., non-musc., med. & elong.	6.28	6.04	6.08	5.45
Med. plump, non-muscular	3.21	3.08	3.10	3.06
Thin, non-musc., elongate	2.63	3.78	3.59	2.93
Very fat, med. musculature	2.43	3.44	3.29	2.66
Sub-med., muscular	3.07	2.24	2.37	2.36
Thin, sub-med. musc., elongate				

TABLE 56 - 3 (Continued)

	Flight	Ground & Others	Total AAF	Total Series
Fat, muscular	2.34	1.76	1.35	1.79
Very fat, non-musc., sub-med. musc.	.58	2.57	2.25	1.78
Balanced, tall	1.02	.87	.89	.81
Thin, med. musculature	2.77	.81	1.13	.69
Very fat, very muscular	.58	.50	.52	.49

TABLE 56 - 4

Total Distributution of Whites and Negroes

	% Whites	% Negroes
Thin, non-muscular, elongate	2.94	5.05
Thin, sub-med. musc., elongate	2.27	3.28
Thin, med. musculature	.69	.60
Sub-med., non-musc., med. & elongate	5.45	6.23
Sub-med., sub-med. musculature	14.70	27.86
Sub-med., med. musculature	6.86	12.42
Sub-med., muscular	2.38	1.30
Med. plump, non-muscular	3.05	1.87
Med. plump, sub-med. musculature	17.70	13.44
Balanced, short to medium	16.52	16.32
Balanced, tall	.81	.29
Med. fat, muscular	5.55	1.77
Fat, non-musc., & sub-med. musculature	6.56	3.61
Fat, med. musculature	7.79	3.41
Fat, muscular	1.79	.39
Very fat, non-musc., sub-med. musc.	1.78	.92
Very fat, med. musculature	2.65	.69
Very fat, very muscular	.49	.07

57. Isaac, F.O. Anthropometrical Measurements. A paper presented at the Commonwealth Conference on Development, Design and Inspection of Clothing and General Stores, 2nd London, July 1947.

This report gives a tailor's viewpoints on the status of anthropometry. The author summarizes the contents of his paper as follows:

"(a) In the Inspectorate of Clothing the technical staff responsible for drawing up specifications with size measurements for garments are qualified tailors and, therefore, have a knowledge of anthropometry.

"(b) A large scale investigation might divulge new data in regard to body measurements and proportionate development but such an investigation would be expensive and possibly not desirable for the purpose of improving the fitting of uniform clothing.

"(c) The statistical information gleaned from the large scale American surveys would be of little value in this country.

"(d) Fitting trials would assist in arriving at correct measurements and the quantity of garments in each size to be ordered.

"(e) In fixing the original size roll the number of sizes required will depend on the use and style of the garments.

"(f) Highly paid experts with wholesale clothiers have given much attention to the problem without solving it and it appears that with stock sizes one can only fit some of the people some of the time but not all the people all the time.

"(g) Errors in the initial computation of quantities required in each size can be corrected by the Provision Branch on the second, third and later demands but fitting trials in the first place for new garments might assist in avoiding errors in the number of each size to be ordered.

"(h) Those responsible for issuing clothing should be more competent and take greater care to ensure that each man, if he can be fitted from stock, receives the size that will fit him best.

"(i) Any increase in the number of stock sizes will embarrass the quartermasters, storeholders, etc.

"(j) Height and breast measurements are more reliable guides to fitting than height and weight, the latter being difficult to apply to ready-made clothing. If waist and seat measurements can also be supplied for trousers, shorts, kilts, etc. they will be found most useful.

"(k) Reasonable tolerances must be permitted in the inspection of clothing and slight variations in measurements of garments marked the same size might be a good thing if pains are taken in issuing. In regard to clothing, the tolerances should not be made known to the contractors.

"(l) At present, some Commanding Officers might order uniforms to be altered to a smarter fit in direct contravention to the views of the Medical Branches and the necessity exists not only for fitting trials attended by physiologists and Service doctors, but also for publicising the fact that such trials do take place.

The paper is seven pages long including a bibliography of 13 items. There are no data.

58. King, Barry G. Functional Cockpit Design. Aeronautical Engineering Review, Volume 11, No. 6, June 1952, pp. 32-40.

This article emphasizes the need for the human engineering of the airplane cockpit and stresses the fact that classical or standard anthropometry is often inappropriate to the determination of the most desirable cockpit dimensions. The author stresses that what is needed for functional cockpit design is an anthropometry of "natural" cockpit situations. By "natural" the author means body conditions that parallel those of normal operation or function, as distinguished from the posed body conditions dictated by standard anthropometric techniques. For example, King states, "Values for both eye level and sitting height when maintaining a natural easy sitting position are about one-and-one-half to two inches less than when measured under the standardized (and sometimes artificial) postures used by anthropologists for comparison of races and groups."

The report is eight pages long. It contains seven tables and three figures. The data presented are from the report.

TABLE 58 - 1

Sitting Height and Eye Level (in Inches) of Men Measured in Anthropometric and Natural Sitting Postures (N = 100)

	$\bar{x}$***	$\pm s\bar{x}$	$\pm s$
Anthropometric* sitting height	36.20	0.132	1.32
Natural** sitting height	34.79	0.125	1.25
Anthropometric* eye level	31.32	0.126	1.26
Natural** eye level	29.66	0.124	1.24

*Standard anthropometric technique.
**Measured in natural easy sitting posture.
***$\bar{x}$ = mean, $\pm s\bar{x}$ = standard deviation of mean, and $\pm s$ = standard deviation.

TABLE 58 - 2*

Reach Measurements: The Maximum Distances at Which a Large Percentage of a General Pilot Population† Will Be Able To Reach and Operate Manual Controls Located at Various Points in the Working Area[2]

Level (Inches) Above Seat Reference Point	Angle (Degrees) 0	R15	R45	R75
46	11.6	13.7	15.0	17.0
40	18.9	20.5	22.4	24.1
34	22.9	24.9	26.6	28.0
28	25.5	27.1	29.1	30.1
22	26.7	28.2	30.3	31.4
16	26.6	28.0	29.7	31.6
10	25.3	27.0	29.3	30.4
4	22.6	24.2	26.4	27.9
−2	17.5	19.7	21.8	22.8

* Distances for right arm reach are measured from the vertical line through the reference point with the subject's shoulders touching the back cushion; seat back 13° from the vertical. The reference point is taken as the upper level of the seat cushion at its line of intersection with the small lower cushions of the back pad (Warren McArthur seat). R15° stands for 15° to right. Reach for left arm can be outlined by using above measurements at corresponding points to the left of 0°.

† These distances were suitable for 97.7 per cent of the 139 subjects studied at each position, and suitable for 93 per cent of the group at all positions.

TABLE 58 - 3

Mean Distances for Forward Head Movement of Seated Subjects Restrained by Lap Safety Belt[16]

Test Condition	3-In. Belt, N = 100: $\bar{x}$, In.	$\pm s\bar{x}$, In.	$\pm s$, In.	2-In. Belt, N = 96: $\bar{x}$, In.	$\pm s\bar{x}$, In.	$\pm s$, In.
* Natural	31.04	0.16	1.632	32.09	0.16	1.592
Static-suspended weight	34.00	0.15	1.509	34.11	0.16	1.600
Dynamic-drop weight	37.05	0.17	1.712	36.66	0.20	2.012

* Natural refers to maximum forward position of head which can be voluntarily assumed without action of suspended or drop weights.

TABLE 58 - 4

Relation of the Comfort Knee Angle to the Pedal Distance (in Inches) As Measured from the Seat Reference Point (Measurements Represent Values and Averages for the Three Subjects in Each Group)[11]

Body Type	Leg Length (inches) T1	T2	T3	Seat Height (inches)	Distance to Pedal From Reference Point (inches)* Horizontal T1	T2	T3	Av.	Vertical below R.P.	Angle of knees T1	T2	T3	(degrees) Av.
Tall	45.7	44.0	44.5	15	37.5	35.5	38.5	36.8	10	109	110	122	114
				12.5	38.3	36.5	37.5	37.4	7	108	108	112	109
				10.5	39.3	35.3	36.7	37.0	5	114	104	109	109
	M1	M2	M3		M1	M2	M3			M1	M2	M3	
Medium	44.0	42.7	42.0	15	35.3	34.5	35.3	35.0	9	109	110	114	111
				12.5	38.0	33.3	35.0	35.4	7	110	111	105	109
				10.5	36.7	34.7	35.2	35.6	5	105	112	103	107
	S1	S2	S3		S1	S2	S3			S1	S2	S3	
Short	38.7	38.5	42.1	15	35.7	30.3	31.5	32.5	8	110	113	104	109
				12.5	34.3	32.0	35.0	33.7	5	106	114	102	107
				10.5	32.7	34.0	34.5	33.8	3	99	117	110	109

* Reference point is the same as that described for arm reach measurements (Table 5). N = 9; the percentile points for subjects, when placed in height distribution for series of 2960 AAF cadets[7/], are 91.9, 91.9, 76.4, 62.1, 57.9, 21.5, 17.0, 15.9, and 15.9. For purposes of comparison, this group of nine men has been split into three equal groups by height -- tall, medium, and short.

59. King, Barry G., Dorothy J. Morrow, and Erwin P. Vollmer. Cockpit Studies - The Boundaries of the Maximum Area for the Operation of Manual Controls. Report No. 3, Project X-651, Naval Medical Research Institute, National Naval Medical Center, Bethesda, Maryland, 15 July 1947.

"The boundaries of the maximum working area for operation of manual controls may be represented by a segment of the shell of an ellipse; the shell is about five inches thick. The maximum dimension to the periphery of this shell is found at approximately shoulder height at 105° to the right or left; dimensions diminish as the arm is brought to the zero position and as the arm is raised or lowered.

"Average reaches for 139 subjects varied between 36.8 inches and 13.1 at various points on the elliptical segments; dimensions within 0° and 75° satisfactory for 93 per cent of the sample varied from 31.6 to 11.6 inches when seat back was 13° from vertical." Anthropometric measurements are given for a large number of subjects. The problem of representative samples of the military population is discussed. A simple rapid method for further testing of dimensions, selection of pilots and studying placement of controls is described.

The report is 47 pages long, including 12 tables, nine figures, and three appendices. The bibliography contains eight references. Two figures are included with this annotation.

See also: King, Barry G. Functional Cockpit Design. Aeronautical Engineering Review, Volume 11, No. 6, June 1952, pp. 32-40.

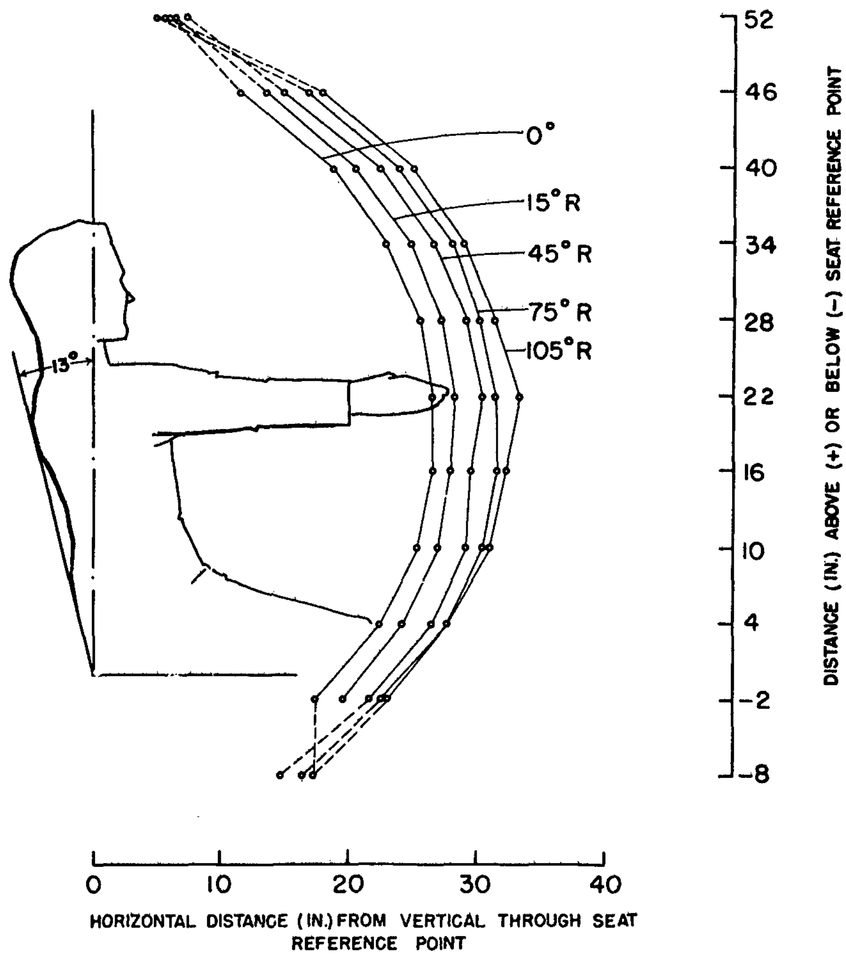


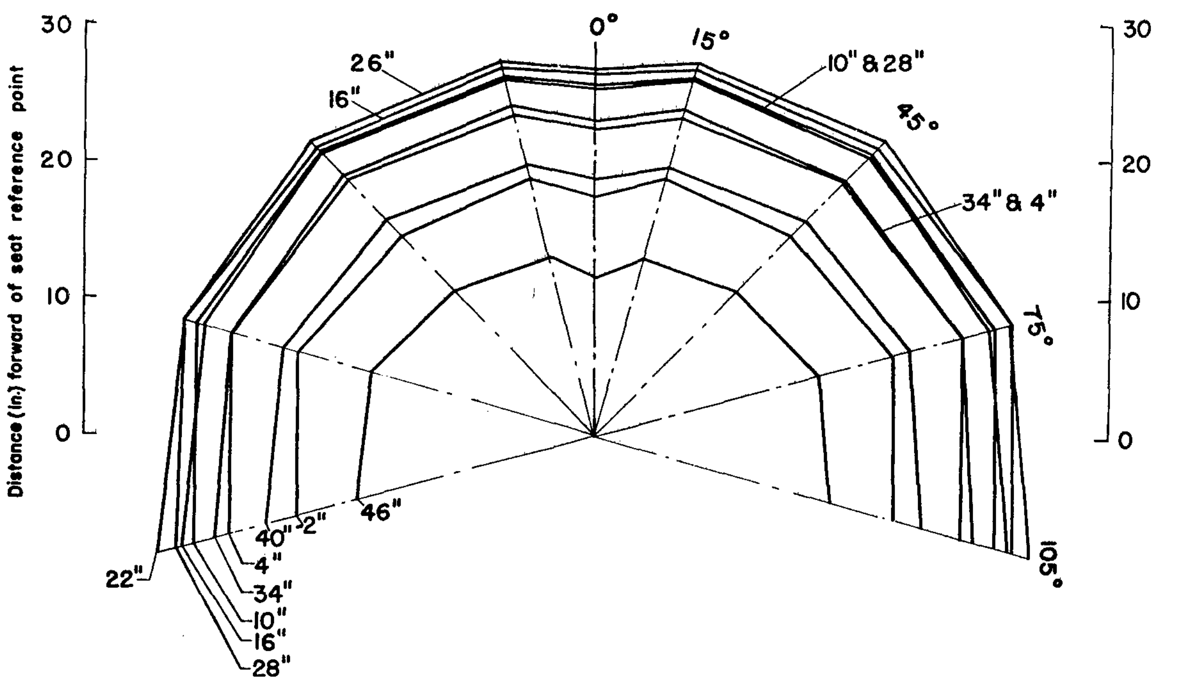
FIGURE 59 - 1

Vertical Reach Distances

Maximum distances which can be reached by 97% of the population at each position. The elliptical arcs indicate the maximum boundaries of the working area for operation of manual controls (at right angles from 0° to 105° to the right) for this group. Seat back angle 13°.

FIGURE 59 - 2

Horizontal Reach Distances



Maximum distances which can be reached by 97 per cent of the population at each position. The eliptical arcs indicate maximum boundaries for this group for operation of manual controls at various horizontal levels. Seat back 13° from vertical

60. Lasker, Gabriel W. Migration and Physical Differentiation: A Comparison of Immigrant with American-born Chinese. American Journal of Physical Anthropology, New Series, Volume 4, No. 3, September 1946, pages 273-300.

In the present study 284 adult males were measured. Ninety-seven were Cantonese immigrants, 48 were American-born of Cantonese extraction, 5 were Hawaiian-born, 9 Cantonese were born elsewhere and the remainder came from other parts of China. The measurements were made in cities in the eastern United States between November. 1940 and May 1942. The measurement methods of Martin (Martin, R. Lehrbuch der Anthropologie.) "were followed without significant modification with the following exceptions. Weight was taken with a spring scale which was not very accurate. Limb measurements were taken on the left side. The arm was measured from the anterior border of the acromial process with the limb extended in front of the subject, a method giving a smaller dimension than the Martin technique. The same position was used in the measurement of the segments of the arm. Tibal length was taken with the subject sitting and the left ankle supported on the right knee. Femoral length was omitted from the schedule because of the difficulty of accurately locating the greater trochanter. Hand breadth and foot breadth were taken from the medial border of the first to the lateral border of the fifth metacarpo-phalangeal and metatarso-phalangeal joints respectively. All subjects were examined with their trousers on which may account in part for the unduly high figures for bi-iliac diameter. Chest measurements, particularly depth, were difficult to take accurately. Projected measurements of head height was taken with the anthropometer and is not very accurate. It appears probable that I have located nasion slightly above the bony nasion to judge from a check of nasal and facial heights with skeletal material; however, the deviation is probably constant and not greater than in most previous studies of living Chinese. In measuring nasal breadth I have used care not to compress the nasal wings in consequence of which my measurements tend to be greater than those of other investigators. The nasal salient was measured by projection."

It was concluded "that measurements of Chinese males born and raised in the United States differ in certain specific respects from those of Chinese immigrants born in China. These differences consist in an increase in stature and in all measurements highly correlated with stature: notably all measurements of the trunk and limbs other than chest depth. Of the body indices, the thoracic, brachial, hand and foot indices tend to be lower in the American-born. Such changes are not limited to Chinese in continental United States. Similar tendencies have been noted for Chinese and Japanese born in and immigrant to Hawaii.

"In the case of the head and face, differences between American-born and immigrant Cantonese are less significant. The American-born Chinese have wider and shorter heads, and have longer, narrower, higher noses and longer faces.

"The tendency towards a broader, shorter head and lower nasal, nose salient, fronto-parietal, cephalo-facial, fronto-gonial and zygo-gonial indices is found also in Chinese and Japanese born in Hawaii. The tendency to an increase in facial lengths, though reported also for Chinese males born in Hawaii, seems not to hold for Japanese.

The 27 pages of this article include 3 tables, 1 figure, and 52 bibliographic references. One table, of anthropometric data.are included in the annotation.

TABLE 60 - 1

Measurements and Indices on Immigrant and American-born Chinese

	AMERICAN-BORN CHINESE			IMMIGRANT CHINESE			DIFFERE[NCE]
	Mean	σ	Range	Mean	σ	Range	Mean
Number	48			97			
Age (years)	23.0	4.4	18–42	27.7	8.0	18–60	— 4.64
Age at migration (years)				17.0	5.0	1–33	
Weight (lbs.)	131.8	13.4	104–162	128.8	21.7	96–240	2.95
Stature (mm)	1676.3	51.7	1593–1797	1655.6	54.1	1513–1766	20.69
Sitting height	895.0	26.3	844–956	888.0	30.6	811–946	6.99
Span	1734.8	62.0	1624–1875	1705.5	62.0	1561–1856	29.80
Total arm length	711.8	30.9	642–778	698.1	27.6	621–754	13.64
Upper arm length	292.2	17.0	250–335	285.6	15.0	242–316	6.62
Lower arm length	250.4	11.8	227–276	243.1	11.9	216–268	7.27
Hand length	186.1	8.1	168–207	185.1	8.2	165–201	1.04
Hand breadth	81.2	2.7	77–88	79.4	4.5	71–91	1.75
Lower leg length	369.2	17.8	330–412	362.6	14.3	330–400	6.53
Foot length	255.9	9.7	238–279	249.4	10.3	226–270	6.47
Foot breadth	97.3	4.6	85–109	97.1	5.0	85–110	.26
Biacromial diameter	391.4	16.8	361–430	387.6	17.5	346–444	3.80
Biiliac diameter	288.3	17.3	242–347	283.1	20.2	238–375	5.18
Chest breadth	276.5	13.3	255–303	273.1	22.9	222–389	3.38
Chest depth	198.2	16.9	157–257	201.5	18.4	167–288	— 3.27
Head length	187.2	7.1	177–202	188.4	5.9	175–204	— 1.21
Head breadth	154.8	5.2	143–170	153.3	5.1	139–166	1.55
Head height	129.0	5.3	116–139	130.5	4.9	121–142	— 1.48
Minimum frontal diameter	102.6	4.6	92–113	102.2	4.7	92–117	.41
Bizygomatic diameter	142.2	5.2	131–155	141.1	5.7	124–155	1.12
Bigonial diameter	107.3	5.2	96–120	106.9	6.0	93–120	.40
Interocular diameter	32.3	3.2	27–42	32.4	2.7	25–39	— .10
Total facial height	124.6	6.2	113–136	121.8	5.3	109–134	2.72
Upper facial height	73.5	4.8	64–83	73.2	4.5	59–85	.21
Nose height	55.5	3.0	49–62	53.4	3.4	45–61	2.13
Nose breadth	40.4	2.1	35–47	40.5	2.5	35–49	— .09
Nose salient	22.9	2.0	18–25	22.5	2.3	16–28	.40
Relative span	103.48	1.82	99–108	103.02	2.16	97–108	.46
Relative shoulder breadth	23.49	.79	22–25	23.41	.82	21–25	.08
Shoulder-hip index	73.34	4.12	64–88	73.11	4.27	63–86	.23
Thoracic index	71.71	5.39	60–86	73.77	5.10	65–91	— 2.06
Relative sitting height	53.44	1.23	51–56	53.64	1.16	51–57	— .20
Cephalic index	81.80	4.08	72–91	81.42	3.31	72–93	.38
Length-height index	68.20	2.75	63–74	69.30	2.91	63–78	— 1.10
Breadth-height index	83.38	3.97	76–92	85.21	3.85	78–96	— 1.83
Fronto-parietal index	66.44	2.83	59–74	66.71	2.85	60–74	— .27
Cephalo-facial index	91.76	2.41	87–97	92.00	3.11	84–98	— .24
Zygo-frontal index	72.52	3.39	60–82	72.54	3.38	66–86	— .02
Fronto-gonial index	104.54	6.47	92–130	104.75	6.61	88–121	— .21
Zygo-gonial index	75.52	3.16	68–82	75.81	3.51	67–86	— .29
Total facial index	87.12	4.61	78–96	86.47	4.57	76–105	.65
Upper facial index	51.90	4.23	45–64	51.98	3.61	41–66	— .08
Nasal index	73.11	5.52	58–84	76.29	7.02	61–96	— 3.18
Nose salient-height index	40.76	3.77	33–51	42.34	4.47	30–54	— 1.58
Brachial index	84.09	4.55	74–96	85.20	4.10	74–95	— 1.11
Hand length-breadth index	43.64	1.57	41–48	43.73	1.67	39–50	— .09
Foot length-breadth index	38.05	1.34	35–42	38.85	1.80	36–43	— .80

[1] The difference is more than four times the probable error of the mean.
[2] The difference is more than three times the probable error of the mean.

61. Lovell, G. Design and Development of the R.A.F. Dummy of the Standard Airman. Technical Note: No. Mech. Eng. 176, Royal Aircraft Establishment, Farnborough, Hants, England, May 1954 (ASTIA No. AD-38849).

"A dummy of the standard airman has been developed at the R.A.F. for use in dynamic and static tests. It has been designed to the dimensions of the average airman and the limbs and the complete man have approximately the correct weights and centres of gravity. Its all up weight is normally 166 lb but it can be varied from this figure if desired. The dummy has a basic metal structure, covered with foam rubber and articulated at the joints. While it is normally fitted with a simple canvas suit it can be dressed in standard aircrew clothing, equipment, and headgear. There are cavities for instruments in the head and in the upper and lower trunks. A box containing three mechanical accelerometers mutually at right angles can be fitted in each of these cavities."

Each of the series of development dummies is described in terms of construction and associated problems, such as joint types, weight and centre of gravity, shape, instrumentation, dimensions, covering and clothing.

The 26 pages of this report include 4 tables and 24 figures, including detailed construction and dimension drawing of the various models and photographs of the models and their components. Three bibliographic references are listed, including two by G.M. Morant, Cumulative Bibliography references (Morant, G.M. Survey of the Heights and Weights of Royal Air Force Personnel.) and (Morant, G.M. Dimensional Requirements for Seats in R.A.F. Aircraft.), which provided basic anthropometric data for the dummy design. The annotation includes one table and three figures.

TABLE 61 - 1

Weight Distribution of Dummy Men Mks III and IV

Component	% of Total Weight	Weight lbs
Head and Neck (Including a 3 1/2 lb ballast weight)	3.25	13.9
Upper Trunk (Including arm shackles, shoulders and a 6 lb ballast weight)	26.75	44.4
Lower Trunk (Including a 2 1/2 lb ballast weight)	14.5	24.0
Corset	1.05	1.7
Thighs (Including upper knee caps and shackles)	21.7	36.0
Legs and Feet (Including floating knee cap, lower knee cap and pin assembly)	16.5	27.5
Upper Arms	5.45	9.0
Lower Arms and Hands	3.99	6.6
Suit (Including boots and mitts)	1.81	3.0
Totals	100	166

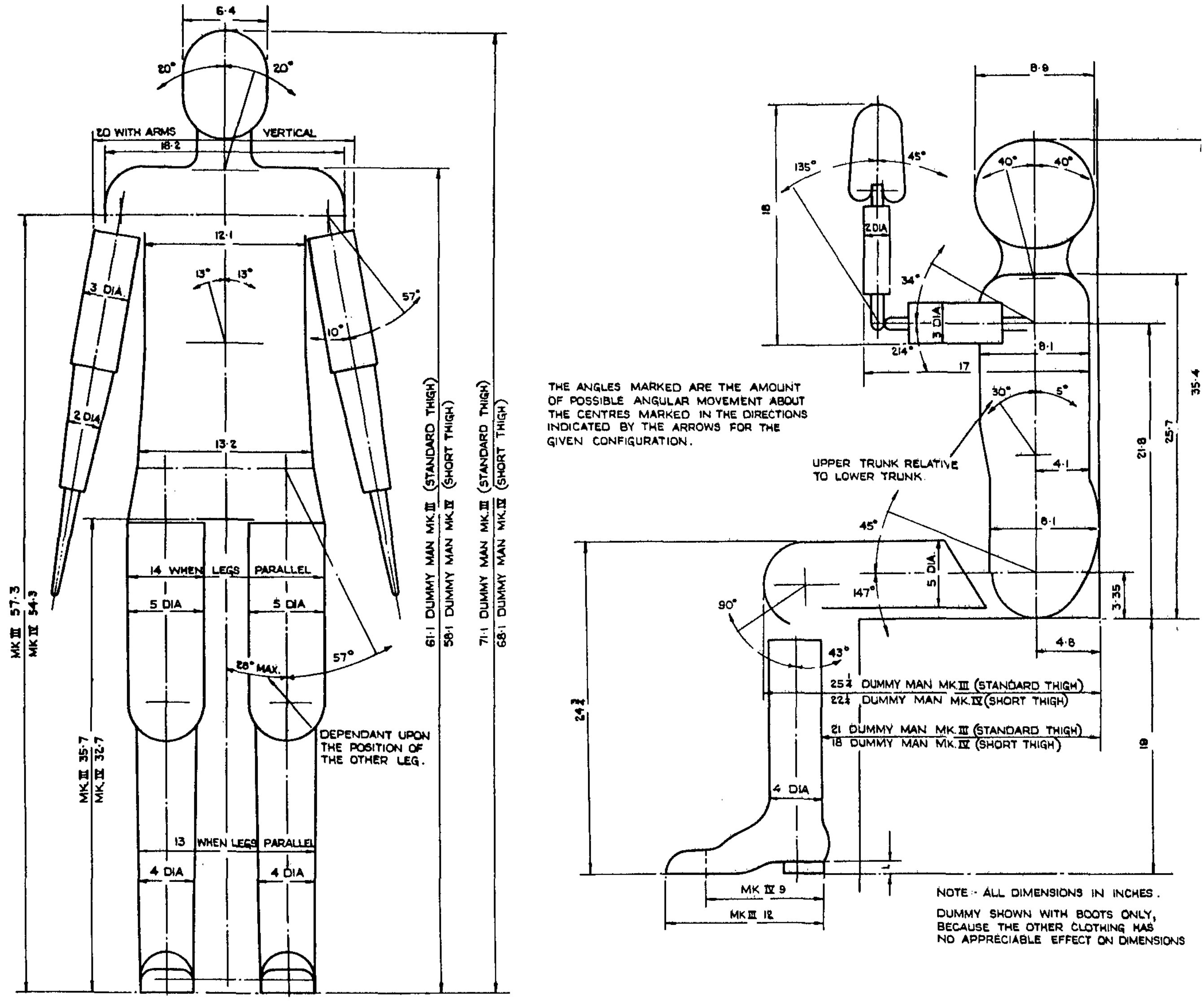


FIGURE 61 - 1

Overall Dimensions and Limb Movements of Dummy Men Mks. III & IV

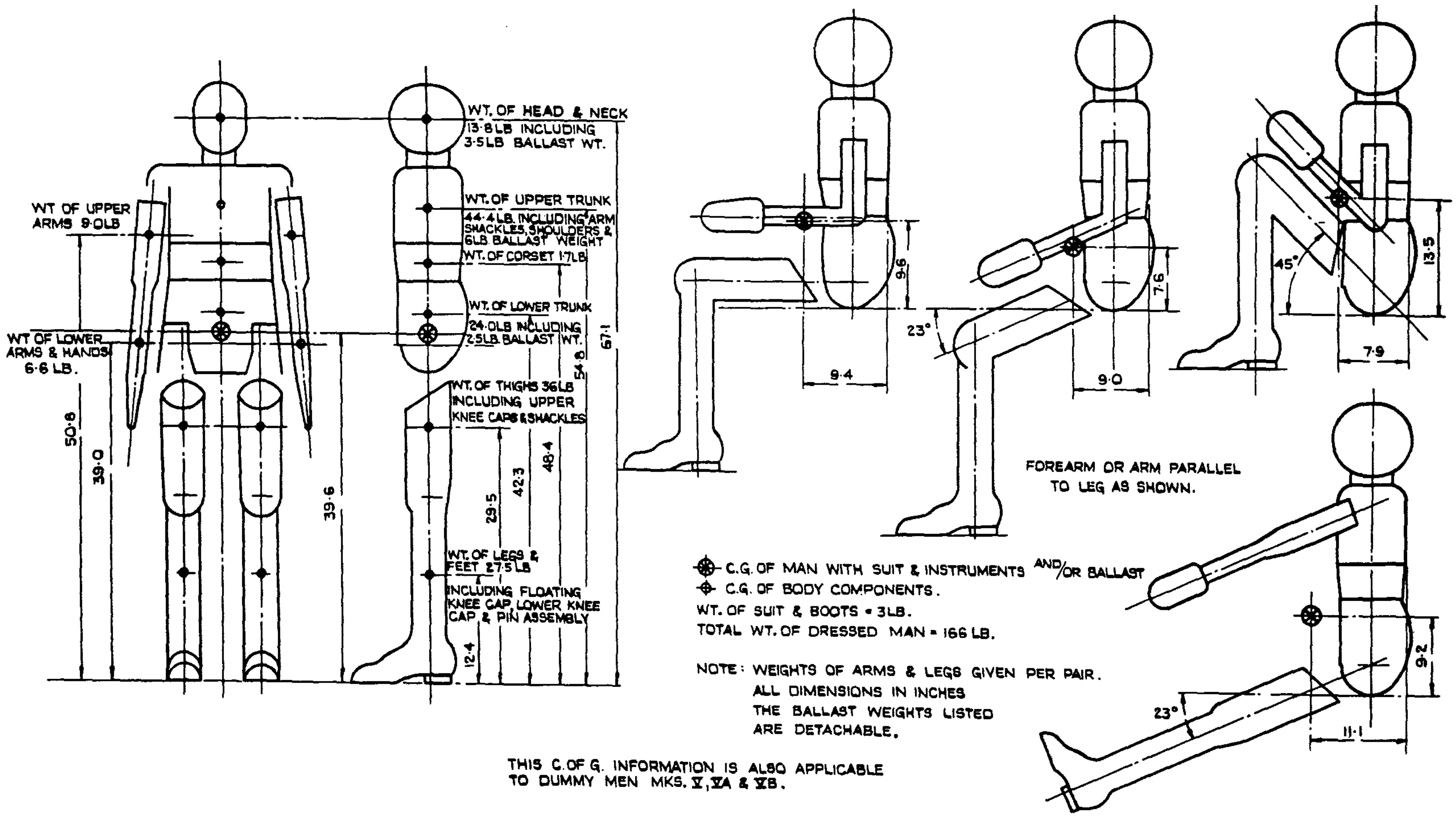


FIGURE 61 - 2

Dummy Man Mk. III (Standard Thigh) Centres of Cravity

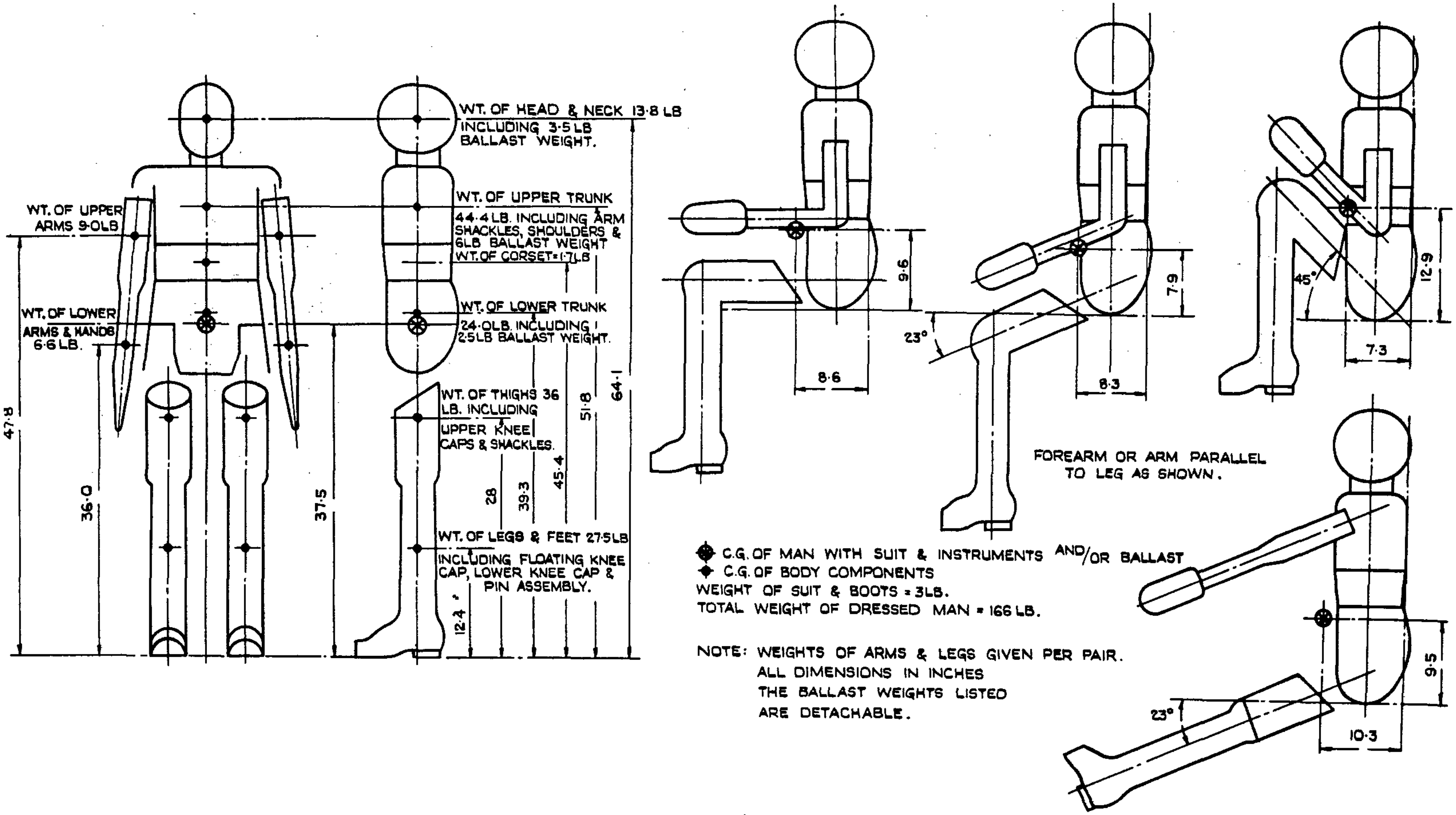


FIGURE 61 - 3

Dummy Man Mk. IV (Short Thigh) Centres of Gravity

62. Martin, W.E. Basic Body Measurements of School Age Children. Washington 25, D.C., U.S. Department of Health, Education, and Welfare, Office of Education, June 1953.

"This publication has been prepared as a ready reference handbook for use by school officials, architects, design engineers, and others who need information on the basic body measurements of school-age children.

"It contains information on the means, the variability, and the range of 53 different body measurements for boys and for girls, for each age from 4 to 17 years. The measurements include the following: heights of different parts of the body from the floor, in standing and sitting positions; lengths of different segments of the trunk; lengths of the limbs and their component parts; depths, breadths, and diameters of different parts of the body as well as their arcs, girths, and circumferences.

"The measurements which are included in this study were selected on the basis of the responses to a questionnaire which was sent to manufacturers, architects, school business officials, specialists in school plant planning, and selected school officials and teachers. Only those measurements are included which these individuals need in their work of building, furnishing, and equipping more 'functional' school buildings for the youth of the Nation.

"These measurements taken alone, or in combination with others, can be used for computing the space requirements of children carrying on the common learning tasks of the classroom and playgrounds; in planning school buildings and the facilities and services which go into them; and in designing, selecting, and purchasing the furniture and equipment which are needed for the different activities of children in the different grades.

"The sources from which the measurements were taken are the published reports of eleven studies on child growth and development which have been conducted during the last quarter of a century and unpublished data from growth studies which are now under way. All of these studies were conducted at centers which are recognized as leaders in the field; the samples of pupils used in the studies were large enough to give statistically reliable results; and in each study the measuring was done by trained anthropometrists." The number of cases in the various breakdowns varies from as few as 20 to as many as several thousand. For the total sample, N = 296,498. (For boys, N = 152,191; for girls, N = 144,307.)

The report is 74 pages long; there are over fifty pages of tables, two graphs, and a bibliography of 22 references. Table 1 of the report, detailing the sources of the basic data of the study, is included herewith.

63. Martin, W. Edgar and others. The Functional Body Measurements of School Age Children. The National School Service Institute, 27 East Monroe Street, Chicago, Illinois, October 1954.

This bulletin provides information "on the body measurements of children in characteristic working positions such as sitting at desks and tables, standing in working positions at laboratory and shop benches, and reaching for books and stored materials on shelves. ...The sample used from 10 elementary and secondary schools in Southern Michigan in the area between Ann Arbor and Detroit."

The bulletin is 90 pages long, contains 34 tables, 26 figures, and four graphs. The bibliography lists 31 reference.

TABLE 62 - 1

Studies Used as Sources of Basic Data for Determining the Body Measurements of Pupils 4 to 17 Years of Age

Code	Study	Date of study	Nature of sample used in study	Number of cases		
				Boys	Girls	Total
1	2	3	4	5	6	7
1	Gray and Ayres	1931	White boys and girls attending private schools in Chicago, Illinois	2,849	1,346	4,195
2	Steggerda and Densen	1931-34	Dutch boys and girls attending public schools in Holland, Michigan, whose ancestors came from the Netherlands	1,906	1,824	3,730
3	Harvard Growth Study	1922-34	Children of N. European, S. European, Negro, Jewish, and mixed stock attending public schools in Medford, Revere and Beverly, Massachusetts	747	806	1,553
4	Meredith and Boynton	1930-35	White boys and girls attending the infant laboratory, preschool laboratory, elementary and high schools at the U. of Iowa	1,013	771	1,784
5	Lucas and Pryor	1935	Middle class, American born, white children representing public school, private office practice, and hospital clinic populations in San Francisco, California	2,135	2,273	4,408
6	Richey	1937	White children from well-to-do and professional classes attending the laboratory schools at the U. of Chicago	1,884	1,871	3,755
7	Lloyd Jones	1936-38	White children attending public and private schools in Los Angeles, California	61,192	60,628	121,820
8	O'Brien (U.S.D.A.)	1937-39	"The general run of white American born boys and girls" in public and private schools, on playgrounds, in camps, and in clubs in 16 States[1] and the District of Columbia	69,661	64,146	133,807
9	Meredith	1939-40	White boys and girls from the professional and managerial socio-economic groups attending the preschool laboratory and elementary school at the University of Iowa	230	220	450
10	Brush Foundation Study	1931-42	White children of N. European ancestry, "who were above average both economically and educationally," from the Greater Cleveland area	515	484	999
11	Wolff (U.S.P.H.S.)	1937-40	White children attending the public schools of Hagerstown, Maryland	10,059	9,938	19,997
12	Bennett	1924-25	Children attending elementary and high schools of the U. of Chicago; Winnetka, Illinois; Cleveland, Ohio; Philadelphia, Pennsylvania; and Des Moines, Iowa			3,700
			TOTALS	152,191	144,307	300,198

1. The sixteen States covered by this study were: Alabama, California, Colorado, Illinois, Iowa, Kansas, Maryland, Michigan, Minnesota, Nebraska, Ohio, Pennsylvania, Tennessee, Texas, Utah, and Virginia

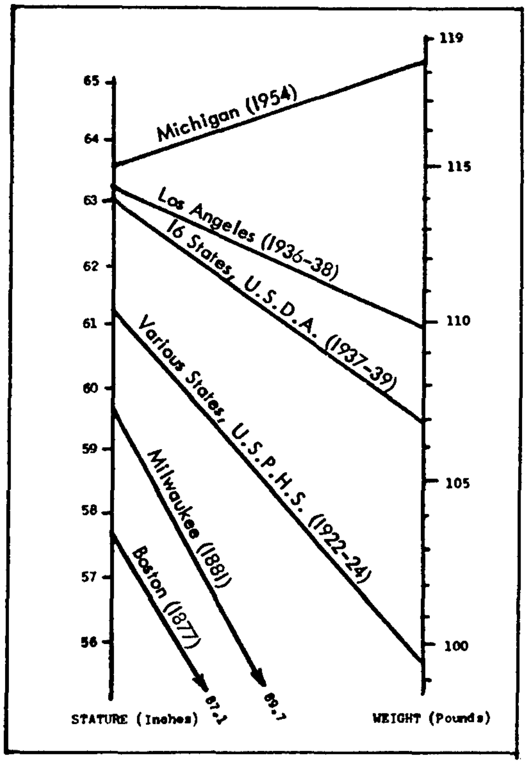


FIGURE 63 - 1

Stature and Weight for 14 Year-old School Boys taken from Various Studies Done in the United States Since 1877

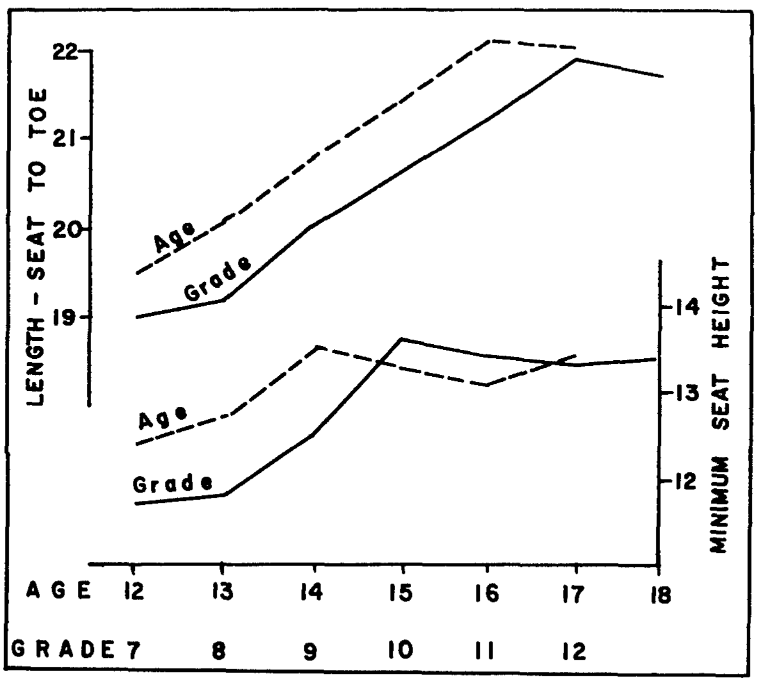


FIGURE 63 - 2

Correlation of Age and Grade with Minimum Seat Height and with Length-Seat to Toe

64. Morant, G.M. Body Measurements and Methods of Sizing Clothing. Commonwealth Conference on Development, Design and Inspection of Clothing and General Stores, 2nd, London, no date. (Paper presented at the conference.)

Background: Inadequacies of fit of R.A.F. flight garments developed by flying personnel caused concern among research workers at the R.A.F. Physiology Laboratory. It soon became apparent that there were no guiding principles for dealing with the sizing problem.

Subjects: The R.A.F. clothing survey provided detailed body measurements on flying personnel (N = 530). Records obtained by using the same technique were obtained for two other groups (flying personnel, N = 2,400; R.A.C. personnel, N = 2,200).

Results: An analysis of these data leads to the following conclusions:

(a) "The differences between the heights and weights of regional communities within Great Britain are so small that for clothing and other practical purposes they can be neglected entirely.

(b) "The average height of British men in general, including those rejected for military service is 67 1/2". This figure has not changed in the past century and it is not likely to do so in the near future. For series of men in the Services averages very close to 68" are always found, except in cases where there is special selection of personnel on account of size (e.g. guardsmen and pilots).

(c) "Judging chiefly from series of flying personnel attached to Bomber Command in 1944, Australian and New Zealand men show almost exactly the same distribution of heights as British men, while Canadians are about 1/2" taller on the average. The men in the Dominion Services tend to be rather heavier than men in corresponding British services, and the differences seem to be marked enough to be of some practical significance in connection with the design and supply of clothing. More extensive data for Dominion series would be needed to establish these conclusions.

(d) "A marked change has taken place in the past 25 years in the age at which maximum height is normally reached. Today it is about the 18th birthday, whereas formerly it was about the 23rd birthday. This secular change is of significance to authorities concerned with the sizing and supply of clothing.

(e) "During the war the normal tendency for body weight to increase between the ages of 20 and 40 was maintained among men in the Services. Normally in the pre-war years the rate of increase was less for men in the Services than for civilians. For the same period of life, civilians in this country failed during the war to show the normal tendency to increase in weight; they increased until about 28 years of age and then remained unchanged. The effect of the war on body weight is of more significance to civilian than to Service clothing questions."

The R.A.F. study indicated that by the use of only two measurements - height and weight - reasonably proper fits of clothing can be predicted.

"The development of any new garment should always be considered as a matter which needs to be investigated in an experimental way. Every new garment is a new problem and trials in the course of its development are absolutely essential. It seems to an outsider, at least, that numerous examples might be given of garments in Service use which might have been made better, and which might have been produced more economically, if trials had been carried out systematically and thoroughly before mass production was started. The energy in terms of money spent on trials during development is a negligible fraction of the money which may be wasted if a specification is imperfect."

The author believes that this systematic approach to the problem can lead to a reduction in the number of sizes of garments required; and furthermore, if experienced tailors administer the fittings, a reduction can be obtained in the number of alterations required.

This paper is 11 pages long. There are no quantitative data. There are no tables or figures. Four references are given.

65. Munro, Ella H. Preparation of Anthropometric Nomographs. Enviromental Protection Division, Report No. 184, Quartermaster Research and Development Command, Natick, Massachusetts, February 1952.

"Seven analyses of Army populations were made in order to present the interrelationships between selected bodily dimensions and two independent dimensions, varying according to the analysis. Each analysis has resulted in a nomograph which is the graphic representation of the interrelationships."

"Presentation of anthropometric data must often take a complex statistical form in order to describe thoroughly the desired relationships; however, in many instances approximation of certain measurements would be sufficient. If such estimates of the required dimensions could be easily obtained without recourse to complicated mathematical calculations, much time would be saved. In order to show such data in a concise and simplified form, several charts have been prepared and are included here. Each of the charts, called nomographs, presents a separate analysis based on some specific set of anthropometric characteristics of an Army population. When values are known for the two independent variables of a given nomograph, mean values of the other dimensions on the chart may be easily determined.

"The first step in the preparation of a nomograph, after the specific purpose for it has arisen, is to determine the two bodily dimensions which will be the independent variables. These must be selected as the best measurements with which to define all the dependent variables. The second step is to decide upon the sizes of interval for each of the independent variables. The size must be small enough to give a workable valuation, yet large enough so that the range of the dimension will not require too many intervals, or 'boxes.' A 'box' may be defined as the area of a bivariate distribution as determined by the limits of the interval of one dimension and the limits of the interval of the second dimension. For example, Stature might be divided into 4-inch intervals and Weight into 40-lb. intervals; hence, one 'box' in this bivariate distribution might then be determined by Stature of 63.0-66.9 inches and by Weight of 100-139 lbs.

"The Army data from which the analyses were made were available on IBM punch cards, and when the sizes of interval were decided, the data were sorted according to the set limits of the two independent variables. Each group thus selected was then sorted serially for each of the dependent variables already chosen for that particular nomograph. Within each group, the mean of the two independent variables was calulated, as well as the mean and standard deviation of each dependent variable. With this tabular form of the data completed, the actual construction of the nomograph began.

"From a consideration of the literature on construction of nomographs, it appears that in most cases an equation was known which represented the interrelationship of the variables in the nomograph. In anthropometric analyses presented here, however, no such equation was known. It is statistically possible to determine an equation which will fit the data fairly well, but the calculations are complex and lengthy.

"In our early work with nomographs, this equation method was used. For example, six of the lines on the Anthropometric Nomograph of Army Women constructed in 1949 were drawn from equations calculated from the tabular data. By inspection of the 'boxes' it could be determined whether the dependent variable followed a linear or curvilinear trend with respect to one or both independent variables. If it was judged to be linear, three values of the dependent variable would be selected from the table on the basis of sufficient frequency in the box and acceptable dispersion in the table. The mean values of the independent variables were known for each box so that with the three selected values of the dependent variable it was possible to set up three equations to be solved simultaneously by simple statistical procedures. The resulting equation expressed the dependent variable in terms of the functions of the two independent variables and a constant. Substitution of the means for the two independent variables for each box in this equation gave a mean value for the dependent variable. This value approximated the dependent variable mean, provided the three boxes selected were representative of the data. If not, the same method had to be applied again, using three different 'boxes'. Obviously, this method is lengthy and tedious. Once an equation was found which satisfactorily agreed with the original data, it was a simple matter to determine by formula where the line would fall in relation to the two set scales of the independent variables, and to establish the unit of the scale of the dependent variable.

"When examination of data clearly indicated a curvilinear trend for the dependent variable, with one or both of the independent variables, the equation method became more intricate and unwieldy. This trend necessitated addition of a squared term in the equations for the independent variable or variables with which curvilinearity appeared. Hence, four or five equations had to be set up and solved simultaneously in order to get the necessary coefficient terms and constant for the final equation. Here again it was a chance selection of values which might or might not give a representative equation. Substitution, in the equation, of given values of the dependent variable and one independent variable would give corresponding values of the other independent variable. When three or more pairs of values were thus determined for the two independent variables at given values of the dependent variable, lines could be drawn on a work sheet nomograph. The intersection of these lines would determine the location of the given points of the dependent variable, and thus of the scale itself. Inasmuch as the curvilinear equations contained one or two squared terms, the solution required reduction of them in the manner of any quadratic equation. When curvilinearity was noted, the assumption was made that the equation would be a modified second-degree polynomial:

$$z = a + bx + cx^2 + dy + (ey^2)$$

whereas the data might actually have been related to an entirely different family of curves. With this basic assumption subject to question, the whole method of construction of nomographs from equations so derived becomes dubious.

"It was at this point in the work with nomographic construction that there was time to make a more thorough investigation of the tabular data with respect to the trends involved, the distances between means of the dependent variables from box to box, and various other vagaries of similarities of the data. The chief purpose of this investigation was to find a simpler and more accurate way of constructing nomographs for anthropometric data. An empirical method was discovered and has been used at this Laboratory exclusively since that time. A specific example is outlined below to demonstrate the method more clearly.

"The Anthropometric Nomograph of Army Men with Stature and Weight as the two independent variables is presented in Figure 1 and is used for the sample problem. Table 65 - 1 illustrates the tabular form of the data from which this nomograph was constructed. The ranges of the independent variables are set by the limits of the sorted data. Each inch of Stature is represented by one inch on the scale on the work sheet nomograph. The Weight scale, with one inch representing ten pounds, is arbitrarily drawn ten inches to the right of the Stature scale. The distance between the scales of the independent variables may vary, inasmuch as the scales of the dependent variables will fall in relative positions on the chart regardless of the distance between the two main scales. The most convenient distance can be determined by plotting in rough draft several lines with varying distances between the two main lines. The best one will contain all the lines in a not too congested area. In certain isolated cases, one scale may fall at a great distance from all other lines on the nomograph. This merely indicates that the correlation between the dependent variable and the two independent variables is so small as to be practically negligible and that it requires a relatively great change in each independent variable, the other being held constant, to show much change in the dependent variable.

"For more convenient use, one dependent dimension has been extracted from Table 65 - 1 and presented together with the mean values of the two independent variables --Stature and Weight. The Hip Circumference means are plotted against the Stature means and against the Weight means on separate work sheet graphs. A work sheet is drawn up, in this case for a one-half-inch scale of Hip Circumference, and from the graphs the values of Stature and Weight for each half-inch are included (see Table 65 - 2). Table 65 - 2 represents the range of Hip Circumference depicted on the nomograph. For each half-inch of Hip Circumference, there must be at least two pairs of values for Stature and Weight. On the work sheet nomograph lines are drawn passing through the tabulated values of Stature and Weight. The intersections of these lines indicate the position and scale units of Hip Circumference. Sometimes because of experimental errors in compilation of the data, or the selection of the random sample or a sample too small to give good results, the straight or curved lines may need smoothing. Such experimental errors will show up in a badly defined intersection, or no intersection at all. Usually, the tabular values that may turn out to be doubtful can be identified by inspection or from the work charts. If one value is definitely out of line with the others, it is preferable, in reading from the chart, either to omit points depending on that particular value, or to interpolate for the value that would fall in line and use it for the work sheet data. When the tentative curve is put in with its scale markings, the tabular data are checked against it to be sure that the line gives the best possible fit for the data.

"If it is evident from inspection of the original tabular data that the relationship is linear, direct interpolation for the pairs of values of the independent variables may be made according to the work sheet scale for the dependent variable. This eliminates the necessity for drawing the two work charts on which the dependent variable is plotted against each of the independent variables.

"Where the range of the dependent variable is small, the work sheet is usually set up by quarters or even tenths of an inch; however, Figure 65 - 5 which is the Anthropometric Nomograph of the Foot deals with such small dimensions that it was drawn by hundredths of an inch.

"After the actual construction of the nomograph is completed, there remains one value to be calculated to give greater utility to the chart. This value is entered at the foot of each line and represents the standard error of estimating the dependent variable from assigned values of the two independent variables. The footnote on each nomograph defines its use. The method of calculating this standard error has been improved since the first nomographs were constructed. In Figures 65 - 3 and 65 - 4 the standard error was approximated by calculating the weighted standard deviations for the dependent variables. As has already been noted, the standard deviation as well as the mean was calculated for each dependent variable in each box. It was a simple matter, therefore, to multiply each standard deviation by the frequency of its box, and to divide the accumulated total by the total frequency. This method gave a value fairly close to the one calculated by the formula now in use.

$$S_e = \sigma_1 \sqrt{\frac{R}{R_{11}}}$$

σ_1 = standard deviation of the dependent variable

$$R = \begin{vmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{vmatrix} \qquad R_{11} = \begin{vmatrix} 1 & r_{23} \\ r_{23} & 1 \end{vmatrix}$$

$$\left.\begin{matrix} r_{11} \\ r_{22} \\ r_{\ 3} \end{matrix}\right] = 1$$

r_{12} = correlation coefficient of dependent variable with one independent variable

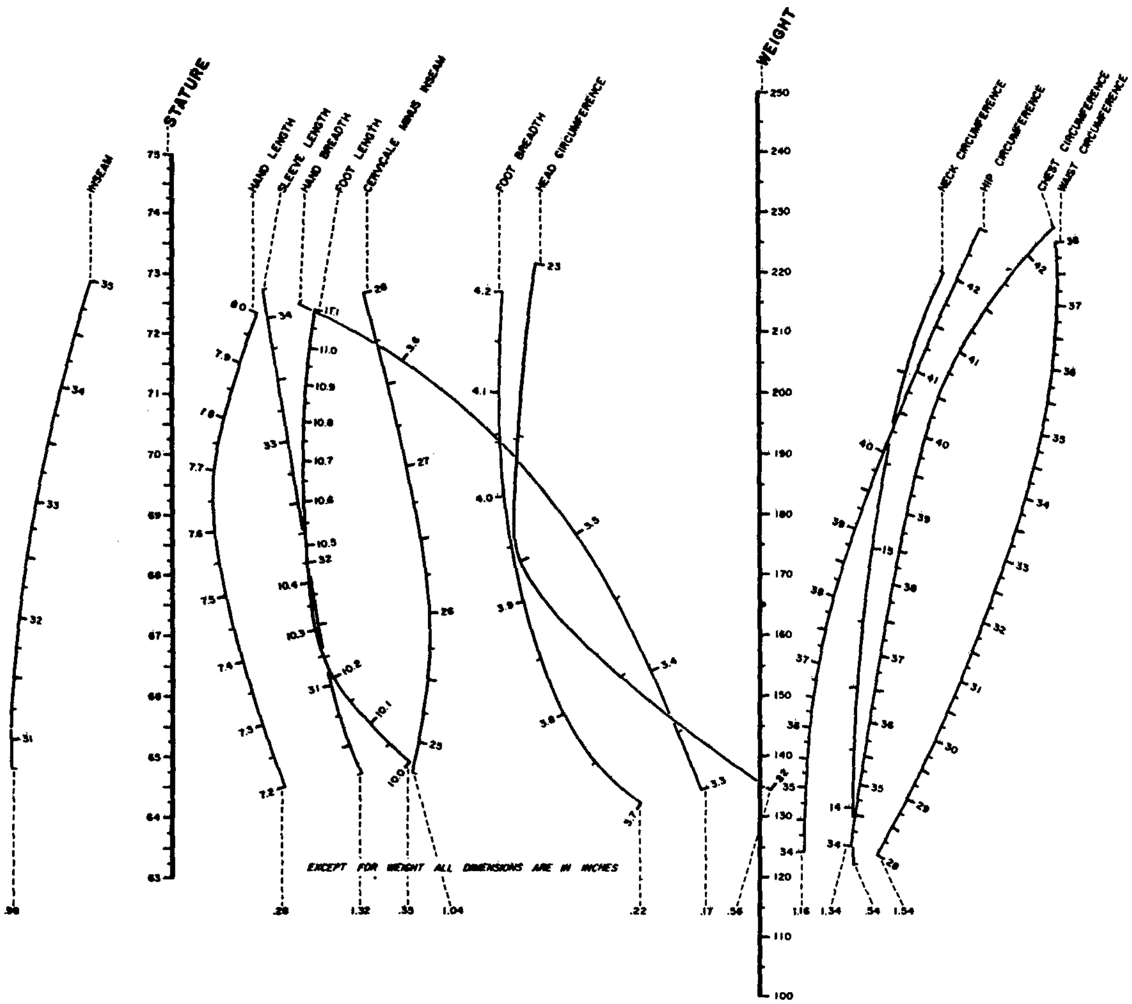
r_{13} = correlation coefficient of dependent variable with other independent variable

r_{23} = correlation coefficient of two independent variables

Substitution of the defined values in the above formula will give an accurate standard error of the estimate.

"In most instances, the available sample had set limits within which the data were sorted. For this reason, the graphs prepared should not be extended beyond those limits. The information available may be insufficient to extrapolate or extend the lines since it is not known what the trend may be outside these limits."

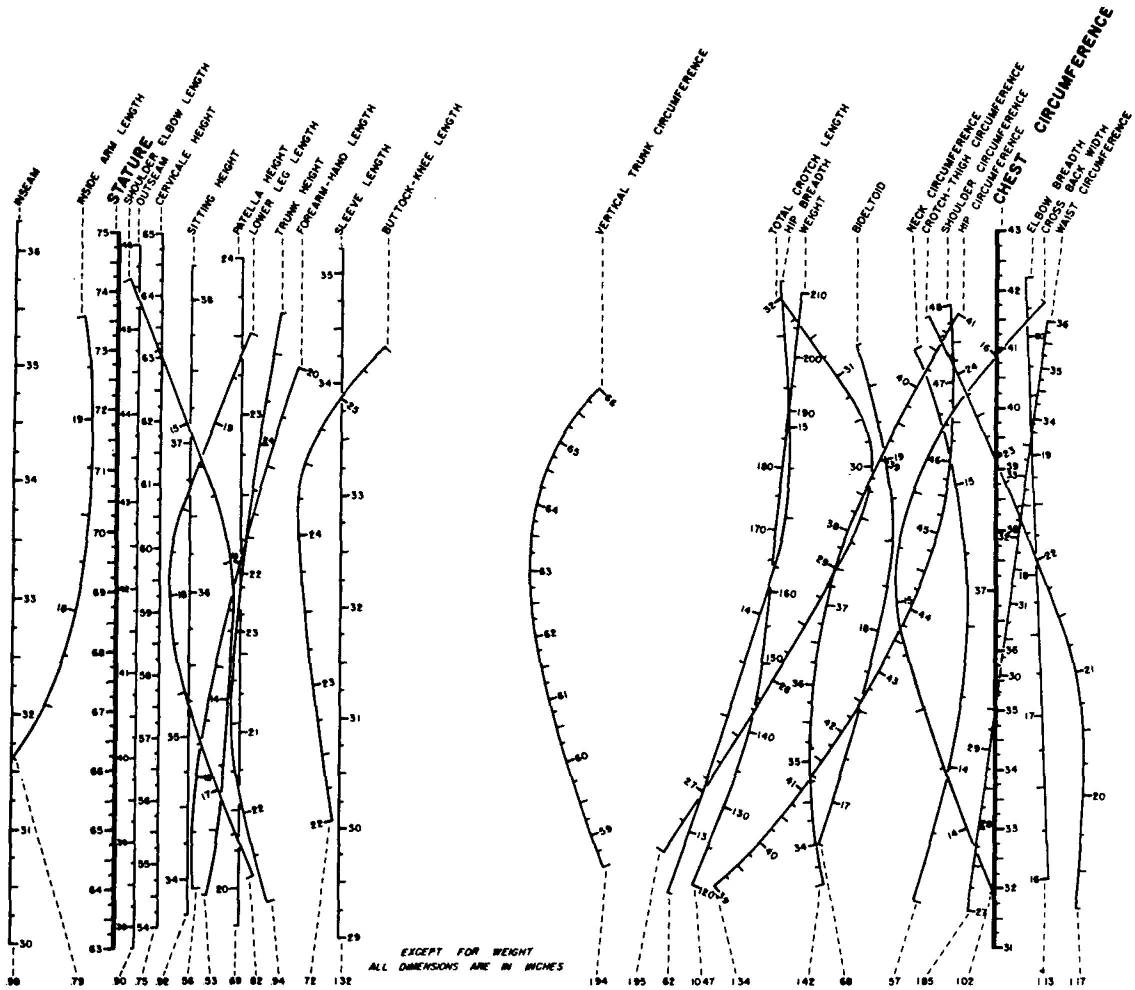
The report is 19 pages long and includes three tables and seven figures. There are three bibliographical references listed as footnotes. The data of the report, including the anthropometric nomographs constructed, are included in this annotation with minor omissions.



A STRAIGHT LINE, PASSING THROUGH KNOWN VALUES OF STATURE AND WEIGHT, WILL ALSO PASS THROUGH AVERAGE VALUES FOR ALL OTHER DIMENSIONS AS SHOWN. EACH AVERAGE VALUE THUS INDICATED IS MID-POINT OF A RANGE DETERMINED BY ADDING AND SUBTRACTING THE AMOUNT SHOWN BELOW EACH LINE TO THE MID-POINT. THIS RANGE WILL INCLUDE ABOUT 67% OF MEN WITH THE ORIGINAL GIVEN VALUES OF STATURE AND WEIGHT.

FIGURE 65 - 1

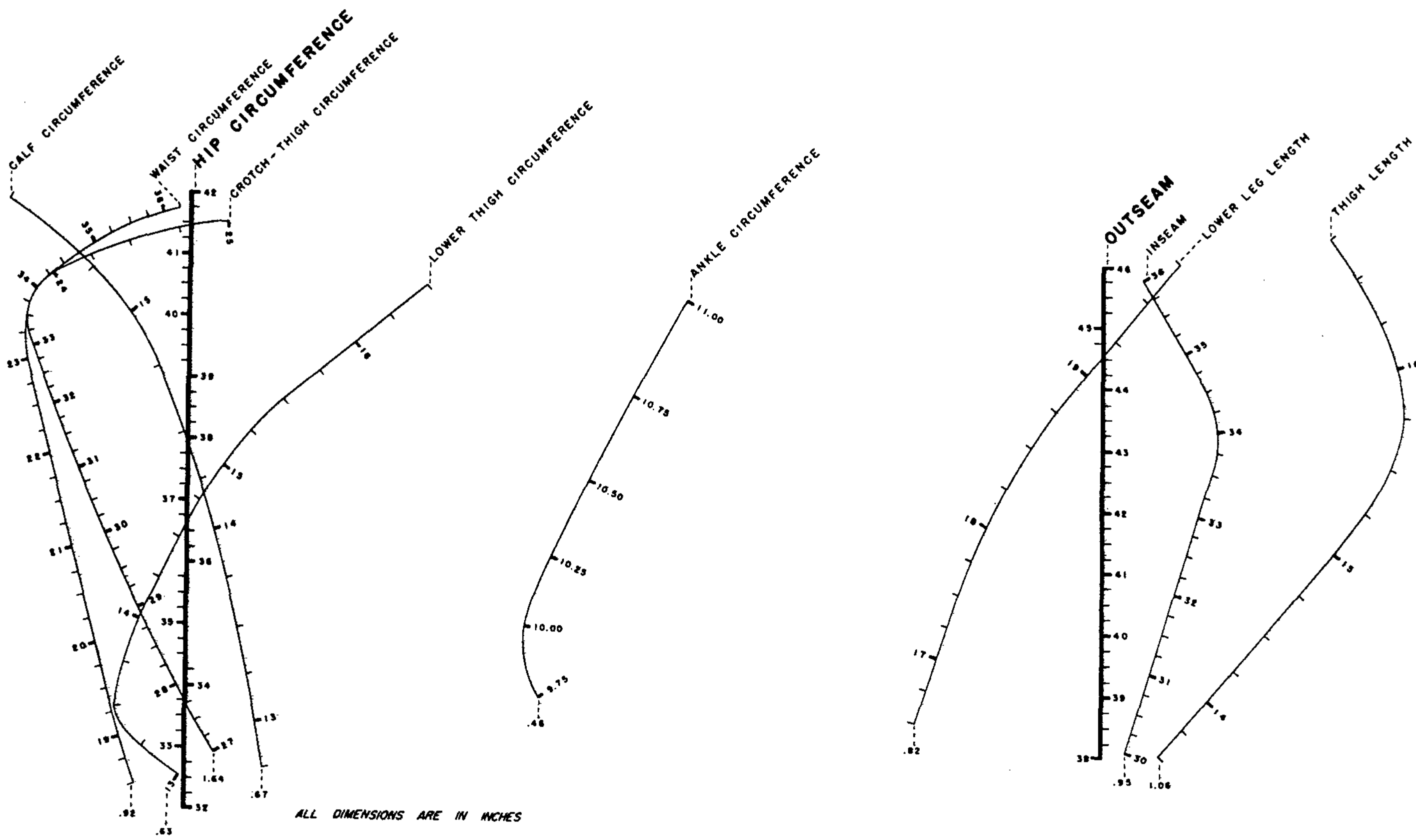
Anthropometric Nomograph of Army Men
U.S. Army White Male
(Basic Variables: Stature and Weight)



A STRAIGHT LINE, PASSING THROUGH KNOWN VALUES OF STATURE AND CHEST, WILL ALSO PASS THROUGH AVERAGE VALUES FOR ALL OTHER DIMENSIONS AS SHOWN EACH AVERAGE VALUE THUS INDICATED IS MID-POINT OF A RANGE DETERMINED BY ADDING AND SUBTRACTING THE AMOUNT SHOWN BELOW EACH LINE TO THE MID-POINT THIS RANGE WILL INCLUDE ABOUT 67% OF MEN WITH THE ORIGINAL GIVEN VALUES OF STATURE AND CHEST

FIGURE 65 - 2

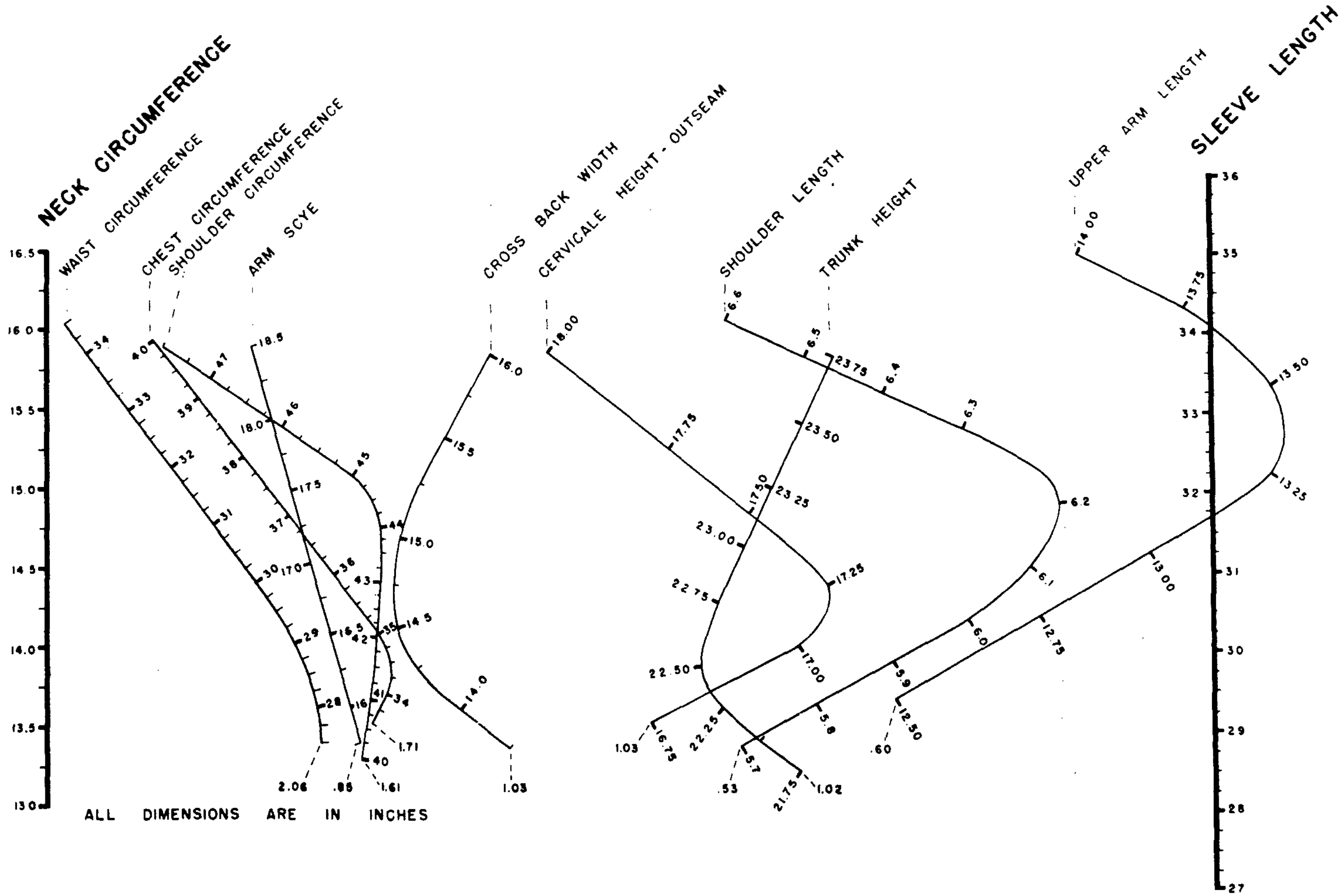
Anthropometric Nomograph of Army Men
U.S. Army White Male
(Basic Variables: Stature and Chest Circumference, Revised)



A STRAIGHT LINE, PASSING THROUGH KNOWN VALUES OF HIP CIRCUMFERENCE AND OUTSEAM, WILL ALSO PASS THROUGH AVERAGE VALUES FOR ALL OTHER DIMENSIONS AS SHOWN. EACH AVERAGE VALUE THUS INDICATED IS MID-POINT OF A RANGE DETERMINED BY ADDING AND SUBTRACTING THE AMOUNT SHOWN BELOW EACH LINE TO THE MID-POINT THIS RANGE WILL INCLUDE ABOUT 67% OF MEN WITH THE ORIGINAL GIVEN VALUES OF HIP CIRCUMFERENCE AND OUTSEAM.

FIGURE 65 - 3

Anthropometric Nomograph of Army Men
U.S. Army White Male
(Basic Variables; Hip Circumference and Outseam)



A STRAIGHT LINE, PASSING THROUGH KNOWN VALUES OF NECK CIRCUMFERENCE AND SLEEVE LENGTH, WILL ALSO PASS THROUGH AVERAGE VALUES FOR ALL OTHER DIMENSIONS AS SHOWN. EACH AVERAGE VALUE THUS INDICATED IS MID-POINT OF A RANGE DETERMINED BY ADDING AND SUBTRACTING THE AMOUNT SHOWN BELOW EACH LINE TO THE MID-POINT. THIS RANGE WILL INCLUDE ABOUT 67% OF MEN WITH THE ORIGINAL GIVEN VALUES OF NECK CIRCUMFERENCE AND SLEEVE LENGTH.

FIGURE 65 - 4

Anthropometric Nomograph of Army Men
U.S. Army White Male
(Basic Variables: Neck circumference and Sleeve Length)

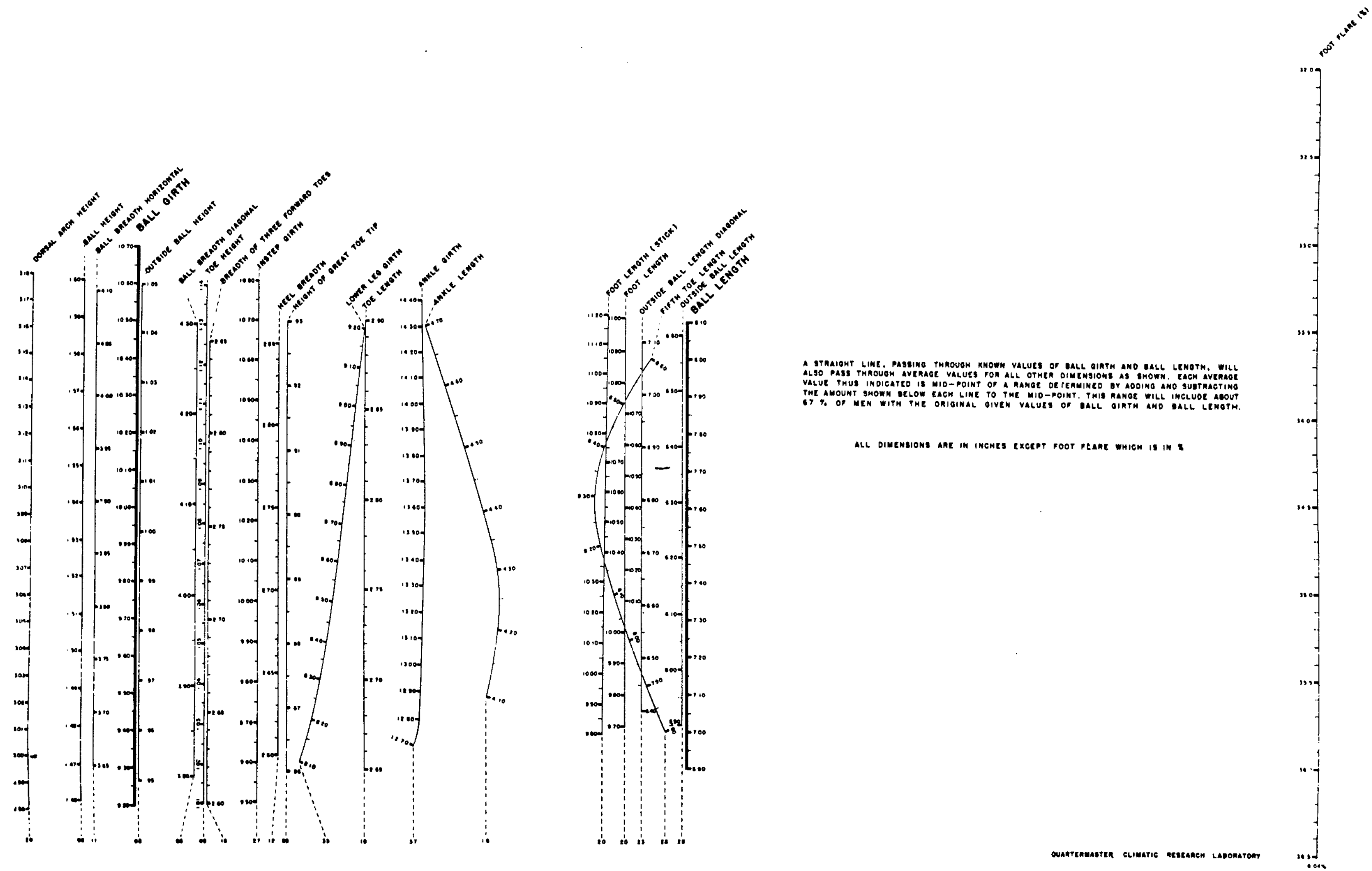
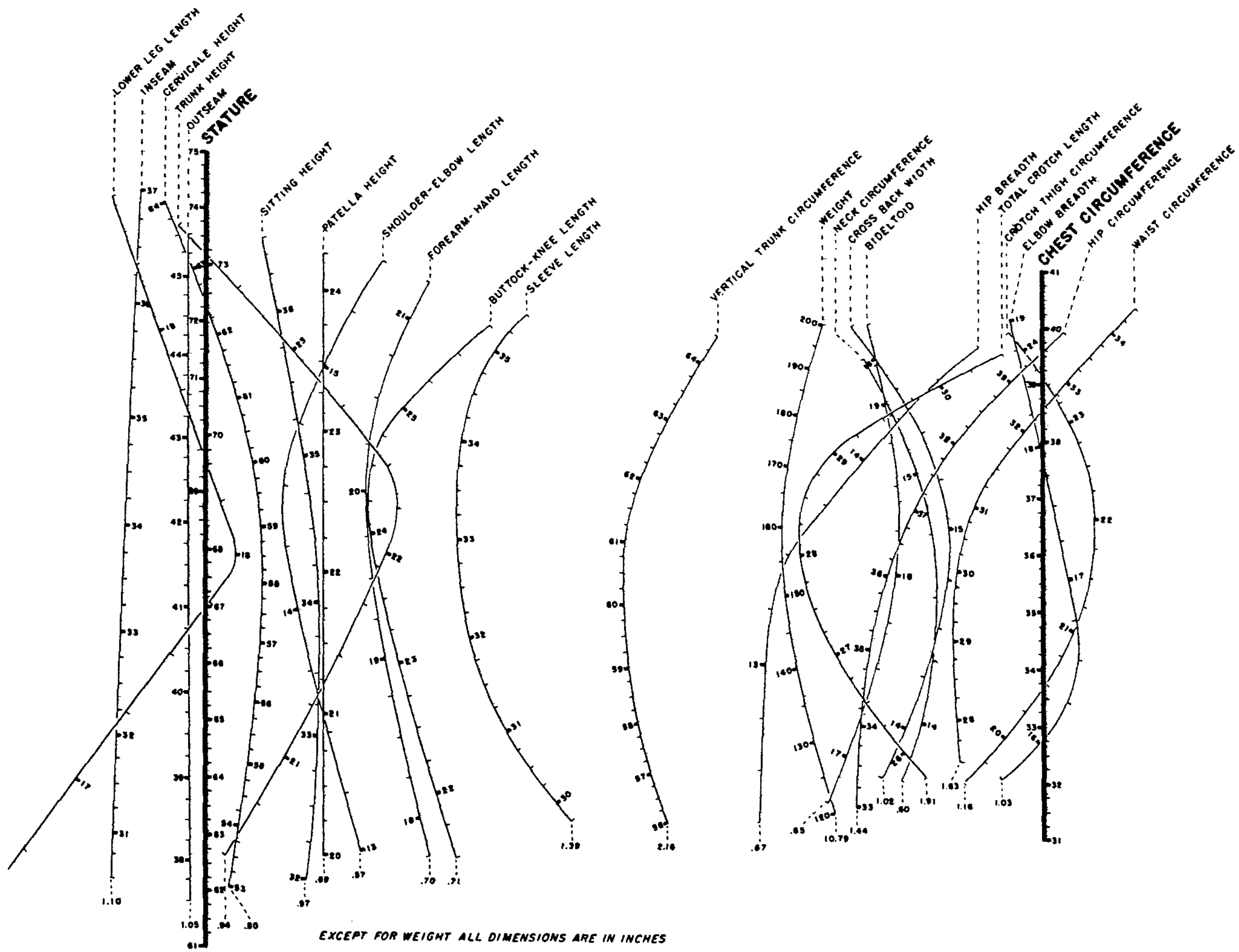


FIGURE 65 - 5

Anthropometric Nomograph of the Foot
U.S. Army White Male



EXCEPT FOR WEIGHT ALL DIMENSIONS ARE IN INCHES

A STRAIGHT LINE, PASSING THROUGH KNOWN VALUES OF STATURE AND CHEST CIRCUMFERENCE, WILL ALSO PASS THROUGH AVERAGE VALUES FOR ALL OTHER DIMENSIONS AS SHOWN. EACH AVERAGE VALUE THUS INDICATED IS MID-POINT OF A RANGE DETERMINED BY ADDING AND SUBTRACTING THE AMOUNT SHOWN BELOW EACH LINE TO THE MID-POINT. THIS RANGE WILL INCLUDE ABOUT 67% OF MEN WITH THE ORIGINAL GIVEN VALUES OF STATURE AND CHEST CIRCUMFERENCE

FIGURE 65 - 6

Anthropometric Nomograph of Army Men
U.S. Army Negroid Male
(Basic Variables: Stature and Chest Circumference)

TABLE 65 - 1

Dimensional Relations to Stature and Weight

Stature 71–75 inches

	Mean	S.D.	Mean	S.D.	Mean	S.D.
Waist Circumference	29.7	1.7	32.9	2.0	38.1	2.4
Inseam Length	35.0	1.2	34.9	1.2	34.7	1.3
Chest Circumference	35.9	1.5	38.6	1.6	42.2	1.9
Cervicale - Inseam	27.0	1.1	27.5	1.1	28.0	1.1
Neck Circumference	14.4	0.6	15.1	0.6	15.8	0.6
Sleeve Length	33.3	1.4	33.7	1.4	34.1	1.3
Seat Circumference	36.5	1.3	39.1	1.5	42.4	1.7
Head Circumference	22.4	0.6	22.8	0.6	23.0	0.6
Hand Length	7.9	0.3	8.0	0.3	8.0	0.3
Hand Breadth	3.5	0.2	3.6	0.2	3.6	0.2
Foot Length	10.8	0.4	11.0	0.4	11.1	0.3
Foot Breadth	3.9	0.2	4.1	0.2	4.2	0.2
	9.226%		6.000%		0.587%	

Stature 67–71 inches

	Mean	S.D.	Mean	S.D.	Mean	S.D.
Waist Circumference	29.1	1.6	32.1	2.1	37.1	2.4
Inseam Length	33.1	1.1	33.0	1.2	32.7	1.3
Chest Circumference	35.1	1.5	37.8	1.7	41.5	1.8
Cervicale - Inseam	25.9	1.1	26.5	1.1	27.2	1.2
Neck Circumference	14.1	0.6	14.8	0.6	15.7	0.6
Sleeve Length	31.8	1.4	32.3	1.4	32.7	1.4
Seat Circumference	35.5	1.3	38.0	1.5	41.6	1.6
Head Circumference	22.2	0.6	22.5	0.6	22.8	0.6
Hand Length	7.6	0.3	7.7	0.3	7.7	0.3
Hand Breadth	3.4	0.2	3.5	0.2	3.5	0.2
Foot Length	10.4	0.4	10.6	0.4	10.7	0.4
Foot Breadth	3.8	0.2	3.9	0.2	4.1	0.2
	29.864%		24.443%		1.839%	

Stature 63–67 inches

	Mean	S.D.	Mean	S.D.	Mean	S.D.
Waist Circumference	28.3	1.6	31.2	2.1	36.8	2.2
Inseam Length	31.2	1.1	31.1	1.2	30.8	1.2
Chest Circumference	34.1	1.5	36.7	1.7	40.7	1.7
Cervicale - Inseam	24.8	1.0	25.4	1.1	26.3	1.1
Neck Circumference	13.9	0.6	14.6	0.6	15.5	0.7
Sleeve Length	30.3	1.4	30.8	1.4	31.4	1.4
Seat Circumference	34.4	1.3	36.8	1.5	40.9	1.6
Head Circumference	21.9	0.6	22.2	0.6	22.5	0.6
Hand Length	7.3	0.3	7.4	0.3	7.4	0.3
Hand Breadth	3.3	0.2	3.4	0.2	3.4	0.2
Foot Length	10.0	0.4	10.1	0.4	10.3	0.3
Foot Breadth	3.7	0.2	3.8	0.2	3.9	0.2
	11.848%		13.178%		0.746%	

STATURE (inches): 75, 74, 73, 72, 71, 70, 69, 68, 67, 66, 65, 64, 63

TABLE 65 - 2

Values of Stature and Weight from Work Charts

Hip Circum-ference	Short Stature		Medium Stature		Tall Stature		Light Weight		Medium Weight		Heavy Weight	
	Stature	Weight	Stature	Weight	Stature	Weight	Stature	Weight	Stature	Weight	Stature	Weight
34.5	65.4	130.4					65.8	130.7				
35.0	65.5	135.5					67.2	136.8				
35.5	65.6	140.1	68.6	142.4			68.7	142.5				
36.0	65.6	145.0	68.7	147.2			70.3	148.7				
36.5	65.7	150.0	68.8	152.6			72.0	154.9				
37.0	65.7	154.5	68.9	157.7	72.0	160.0			66.2	155.1		
37.5	65.8	159.5	68.9	162.8	72.1	165.9			67.6	161.5		
38.0	65.8	164.2	69.0	167.9	72.2	171.1			69.0	167.8		
38.5	65.8	168.8	69.1	172.8	72.2	176.8			70.5	174.9		
39.0	65.9	173.3	69.1	178.1	72.2	182.3			72.0	182.0		
39.5	65.9	178.0	69.2	183.2	72.3	188.1						
40.0	65.9	182.5	69.2	188.5	72.3	193.9						
40.5	66.0	187.0	69.2	193.9	72.3	199.8						
41.0			69.3	199.2	72.3	205.6					66.7	193.3
41.5			69.3	204.3	72.3	211.4					69.0	203.4
42.0					72.3	217.2					70.9	213.6

66. Newman, Russell W. The Assessment of Military Personnel by 1912 Height-Weight Standards. Environmental Protection Division, Report No. 194, Quartermaster Research and Development Command, Natick, Massachusetts, November 1952.

Introduction: Basically, all the so-called standard weight tables "go back to the same concept and even to the same source, the Medico-Actuarial Mortality Investigation of 1909 - 1912 (Medico-Actuarial Investigation. Vol. 1, 1912. The Association of Life Insurance Medical Directors and the Actuarial Society of America). The concept is that of determining the average weight for a large number of adults of the same height, sex, and age. Armed with this information, it is a simple matter to construct a table by which anyone can compare his weight to the average (expressed in whole pounds) for his height and age group."

Advantages to the use of standard weight as a physical criterion include the following:

1. It is easy to measure; most people know their height and weight within reasonable limits.
2. Large amounts of statistical information are available for comparison.

Disadvantages to the use of standard weight are:

1. "The use of weight as the sole criterion obscures the fact that two men with identical height and weight may have markedly different proportions of bone, muscle, and fat."
2. The standard weight is merely the average for a certain range of weights and obviously most people should not be expected to approximate this average.
3. There is no sharp line for delimiting underweight or overweight, weight being a continuous variable.
4. Such data become obsolete by their very nature, since the nutritional status of populations is not, in this century, likely to be static. Further, data collected in one country may not apply, on an individual basis, to other areas.

"This report deals principally with the fourth disadvantage of the standard weight concept as listed above, namely, that tables based on an investigation carried out in 1912 are not appropriate forty years later, and newer data must be incorporated into our thinking and practice.

"It would be even better if the whole concept could be reworked to eliminate all the obvious disadvantages, and the next decade may produce a measure as simple to obtain as standard weight without its defects. In the interim, however, standard weight will continue to be used in many circumstances and it should be based on the latest and best data."

Samples employed: "The data upon which this report is based consist of records on men measured in Quartermaster Corps anthropometric surveys in 1946 and 1949." Three separate series are presented.

1. White male separatees measured in 1946 (N = 28,288).
2. Negroid male separatees measured in 1946 (N = 6,066).
3. White male inductees (N = 12,988) 60 percent of whom were measured in 1946, the remainder in 1949.

"The White separatees represent a geographically weighted sub-sample of a larger series of 85,000 men, while the Negroid separatees and White inductees represent the total available in these categories.

Recommendations: "That new and better data be accumulated to replace the obsolete height-weight standards now in use. That the development of a physical standard criterion which avoids the limitations of relative weight be prosecuted and supported."

The report is 18 pages long including six tables and five figures. Five bibliographic references are included as footnotes. The data of the report are reproduced with this annotation.

TABLE 66 - 1

Age Distribution of Three QMC Anthropometric Survey Series

Age	White Separatees	Negro Separatees	White Inductees
17	413	39	4326
18	991	64	4327
19	2995	1023	1555
20	6925	1665	776
21	1410	605	412
22	1139	478	417
23	1033	439	630
24	938	341	545
25	1007	320	
26	1071	295	
27	911	274	
28	1157	213	
29	1445	158	
30	1377	152	
31	1525		
32	1361		
33	1010		
34	887		
35	693		
Total	28,288	6,066	12,988

TABLE 66 - 2

Percentage Distribution of Relative Weights in White Separatees

Percent Standard Weight	Age 17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
59.6- 64.5									0.10										
64.6- 69.5			0.03		0.07				0.10				0.07				0.20		0.14
69.6- 74.5	0.24		0.03	0.03	0.07		0.19		0.10	0.09	0.22		0.07		0.13	0.07	1.09		0.14
74.6- 79.5		0.10	0.13	0.27	0.21	0.18	0.29	0.75	0.60	0.84	0.66	0.69	0.55	0.80	0.59	0.88	3.66	1.13	1.15
79.6- 84.5	1.21	1.01	0.60	1.05	2.06	1.58	1.55	2.13	1.69	1.87	1.76	2.25	2.84	2.11	2.10	3.09	7.62	4.51	2.74
84.6- 89.5	3.15	4.44	4.21	4.29	4.89	4.30	5.23	4.37	4.57	6.07	5.27	6.14	6.85	7.77	7.41	8.23	14.06	6.76	6.49
89.6- 94.5	14.04	8.68	10.22	10.50	9.72	10.98	9.58	10.98	12.41	13.26	12.62	10.63	11.28	12.49	12.39	13.74	15.94	13.42	11.54
94.6- 99.5	16.22	17.26	15.09	17.24	17.30	15.28	17.62	15.46	15.00	16.81	16.46	17.11	16.75	17.21	16.33	16.24	16.34	18.72	16.74
99.6-104.5	21.55	15.93	18.40	20.59	17.45	19.05	19.36	16.34	20.16	17.74	13.59	17.89	17.99	15.61	17.05	16.53	12.97	14.99	16.16
104.6-109.5	19.61	20.28	18.40	16.91	14.96	19.32	14.33	16.10	14.70	12.88	13.83	13.46	14.26	14.31	14.49	15.14	10.40	12.63	15.73
109.6-114.5	12.35	14.33	12.76	12.26	14.75	11.59	11.62	12.90	9.93	10.74	14.49	11.32	11.14	11.69	10.69	10.80	6.24	11.95	11.83
114.6-119.5	5.81	7.97	9.18	7.70	8.30	7.29	7.55	8.42	9.04	7.56	7.68	7.69	7.61	6.97	7.93	6.61	4.16	7.67	6.64
119.6-124.5	2.66	4.44	4.74	3.77	5.04	5.00	5.90	3.20	4.37	4.95	5.60	6.22	3.39	5.16	4.20	4.12	3.66	4.28	4.62
124.6-129.5	1.94	3.13	2.44	2.30	2.34	2.55	2.03	3.30	3.28	3.18	3.62	3.80	3.74	2.64	3.67	2.13	2.28	1.13	3.03
129.6-134.5	0.48	1.11	1.37	1.17	1.21	1.49	2.42	2.13	1.39	1.31	2.42	1.12	1.87	1.45	1.44	0.96	0.89	1.35	1.30
134.6-139.5		0.60	0.94	0.78	0.71	0.82	1.06	0.96	1.19	0.93	1.32	0.66	0.90	0.87	0.66	0.81	0.30	1.02	0.14
139.6-144.5	0.48	0.20	0.40	0.61	0.43	0.26	0.48	0.43	0.79	0.75	0.22	0.43	0.42	0.51	0.52	0.22	0.10	0.22	1.01
144.6-149.5		0.10	0.23	0.26	0.36	0.18	0.29	0.11	0.20	0.84	0.22	0.26	0.28	0.29	0.20	0.07	0.10	0.11	0.14
149.6-154.5		0.10	0.37	0.03	0.07	0.18	0.10	0.11		0.09	0.22	0.09		0.07	0.07	0.22		0.11	0.14
154.6-159.5	0.24	0.20	0.17	0.13			0.10	0.32	0.10						0.13	0.15			
159.6-164.5		0.20	0.07	0.03	0.07		0.19			0.09									0.14
164.6-169.5				0.03			0.10		0.10					0.14					0.14
169.6-174.5			0.07	0.01															
174.6-179.5			0.10	0.01					0.10										
179.6-184.5				0.03															
184.6-189.5						0.18													
Number	413	991	2995	6925	1410	1139	1033	938	1007	1071	911	1157	1445	1377	1525	1361	1010	887	693
Mean	103.57	105.61	105.99	104.86	105.00	105.07	105.34	105.11	104.93	104.45	105.34	104.66	104.00	103.91	104.03	102.79	103.16	102.60	103.91
Standard Deviation	10.11	11.26	12.01	11.45	11.70	11.70	12.56	12.24	12.68	12.93	12.73	12.27	12.33	12.54	12.36	12.12	12.87	12.16	12.79

TABLE 66 - 3

Percentage Distribution of Relative Weights in Negroid Separatees

Percent Standard Weight	Age 17	18	19	20	21	22	23	24	25	26	27	28	29	30
64.6- 69.5			0.10											
69.6- 74.5						0.42								0.66
74.6- 79.5			0.10	0.18	0.16	0.21		0.29		0.34	0.73	0.47	0.63	
79.6- 84.5	2.56		0.10	0.84	0.66	0.63	1.37	0.59	0.62	1.02	1.10	2.82	2.53	3.29
84.6- 89.5	2.56	3.12	2.64	2.40	1.65	3.77	5.24	4.69	5.00	3.39	6.20	6.10	8.23	5.92
89.6- 94.5	2.56	7.81	6.84	6.49	7.60	7.95	8.88	8.21	13.44	10.17	12.41	15.02	10.13	13.82
94.6- 99.5	12.82	17.19	15.15	15.86	16.03	14.44	16.86	17.30	17.50	13.56	16.06	15.49	15.19	17.76
99.6-104.5	23.08	17.19	18.96	20.06	21.32	18.83	17.31	21.41	18.44	26.44	16.79	17.37	20.25	18.42
104.6-109.5	25.64	21.88	20.92	20.24	20.16	20.29	20.50	16.72	13.44	14.92	17.52	17.37	16.46	15.13
109.6-114.5	15.38	18.75	17.40	15.68	13.72	16.32	9.80	14.66	11.88	13.90	12.04	10.80	12.66	11.18
114.6-119.5	5.13	9.38	8.90	8.65	9.42	8.79	8.88	6.74	7.81	6.44	6.93	5.63	8.23	5.92
119.6-124.5	2.56	3.12	4.79	4.62	4.30	4.39	5.70	5.28	5.31	3.05	5.11	6.10	2.53	2.63
124.6-129.5	5.13	1.56	2.05	2.46	2.98	2.09	2.73	2.64	3.44	3.05	2.92	0.94	2.53	2.63
129.6-134.5			0.78	1.26	0.83	0.84	1.14	1.17	0.94	0.68	1.82	0.47	0.63	0.66
134.6-139.5	2.56		0.78	0.42	0.50	0.63	0.68		0.94	2.37	0.36	1.41		0.66
139.6-144.5			0.29	0.36	0.50		0.46	0.29	0.31					
144.6-149.5			0.20	0.06	0.16	0.42	0.23		0.62					1.32
149.6-154.5				0.12						0.68				
154.6-159.5				0.12			0.23							
159.6-164.5				0.18					0.31					
Number	39	64	1023	1665	605	478	439	341	320	295	274	213	158	152
Mean	106.49	105.28	106.39	106.33	106.11	105.64	105.36	104.92	105.06	105.36	104.17	103.01	102.98	102.95
Standard Deviation	10.43	8.72	9.97	10.60	10.13	10.48	11.46	10.28	12.11	11.47	11.23	11.20	8.44	12.07

TABLE 66 - 4

Percentage Distribution of Relative Weights in White Inductees

Percent Standard Weight	Age 17	18	19	20	21	22	23	24
59.6- 64.5			0.06					
64.6- 69.5						0.24		
69.6- 74.5	0.05	0.09					0.16	0.18
74.6- 79.5	0.21	0.25	0.51	0.77	1.70	0.48	0.48	0.73
79.6- 84.5	1.62	2.24	2.83	2.32	3.16	3.12	3.02	4.40
84.6- 89.5	6.96	6.70	7.27	7.73	7.52	9.35	8.41	7.34
89.6- 94.5	13.98	13.29	13.83	12.89	16.26	13.91	16.03	15.23
94.6- 99.5	21.01	19.78	17.11	17.65	18.69	16.79	18.25	14.86
99.6-104.5	20.44	18.95	17.62	20.36	17.96	17.03	18.25	17.06
104.6-109.5	15.21	15.79	15.82	14.05	15.05	12.47	11.43	14.50
109.6-114.5	8.92	9.52	10.29	11.21	7.04	10.07	7.94	8.62
114.6-119.5	4.46	5.85	4.57	5.03	4.13	7.43	4.92	6.24
119.6-124.5	3.03	3.28	3.60	3.35	1.94	4.08	3.33	4.22
124.6-129.5	1.57	1.46	1.99	1.55	1.70	2.40	2.54	2.57
129.6-134.5	1.06	1.02	1.93	0.77	1.70	0.72	2.06	1.47
134.6-139.5	0.42	0.72	0.84	0.77	1.70	0.24	0.79	0.92
139.6-144.5	0.37	0.39	0.58	0.52	0.73	0.72	1.11	0.73
144.6-149.5	0.25	0.25	0.64	0.26	0.48	0.24	0.32	
149.6-154.5	0.21	0.25	0.13	0.13		0.48	0.16	0.55
154.6-159.5	0.12	0.07	0.19	0.13		0.24	0.16	0.18
159.6-164.5	0.09	0.05	0.06	0.26	0.24		0.48	
164.6-169.5		0.05	0.13				0.16	
169.6-174.5	0.02			0.26				0.18
Number	4326	4327	1555	776	412	417	630	545
Mean	102.40	102.83	103.36	102.94	101.90	102.77	102.90	103.08
Standard Deviation	11.25	11.59	12.89	12.49	12.88	12.77	13.83	13.49

TABLE 66 - 5

Comparison of Graded Average Weight for Different Statures at Various Ages

AGE YEARS		5' 2"	5' 3"	5' 4"	5' 5"	5' 6"	5' 7"	5' 8"	5' 9"	5' 10"	5' 11"	6' 0"	6' 1"	6' 2"	6' 3"
19	1	*128*	*132*	*136*	*140*	*143*	*147*	*151*	*155*	*159*	*162*	*166*	*170*	*174*	*178*
	2	120	123	126	130	134	138	142	146	150	155	160	165	170	175
20		*129*	*133*	*137*	*141*	*144*	*148*	*152*	*156*	*160*	*163*	*167*	*171*	*175*	*179*
		122	125	128	132	136	140	144	148	152	156	161	166	171	176
21		*130*	*134*	*138*	*142*	*145*	*149*	*153*	*157*	*161*	*164*	*168*	*172*	*176*	*180*
		123	126	130	134	138	141	145	149	153	157	162	167	172	177
22		*131*	*135*	*139*	*143*	*146*	*150*	*154*	*158*	*162*	*165*	*169*	*173*	*177*	*181*
		124	127	131	135	139	142	146	150	154	158	163	168	173	178
23		*132*	*136*	*140*	*144*	*147*	*151*	*155*	*159*	*163*	*166*	*170*	*174*	*178*	*182*
		125	128	132	136	140	143	147	151	155	159	164	169	175	180
24		*133*	*137*	*141*	*145*	*148*	*152*	*156*	*160*	*164*	*167*	*171*	*175*	*179*	*183*
		126	129	133	137	141	144	148	152	156	160	165	171	177	182
25		*134*	*138*	*142*	*146*	*149*	*153*	*157*	*161*	*165*	*168*	*172*	*176*	*180*	*184*
		126	129	133	137	141	145	149	153	157	162	167	173	179	184
26		*135*	*139*	*143*	*147*	*150*	*154*	*158*	*162*	*166*	*169*	*173*	*177*	*181*	*185*
		127	130	134	138	142	146	150	154	158	163	168	174	180	186
27		*136*	*140*	*144*	*148*	*151*	*155*	*159*	*163*	*167*	*170*	*174*	*178*	*182*	*186*
		128	131	134	138	142	146	150	154	158	163	169	175	181	187
28		*136*	*140*	*144*	*148*	*151*	*155*	*159*	*163*	*167*	*170*	*174*	*178*	*182*	*186*
		129	132	135	139	143	147	151	155	159	164	170	176	182	188
29		*136*	*140*	*144*	*148*	*151*	*155*	*159*	*163*	*167*	*170*	*174*	*178*	*182*	*186*
		130	133	136	140	144	148	152	156	160	165	171	177	183	189
30		*137*	*141*	*145*	*149*	*152*	*156*	*160*	*164*	*168*	*171*	*175*	*179*	*183*	*187*
		130	133	136	140	144	148	152	156	161	166	172	178	184	190
31		*137*	*141*	*145*	*149*	*152*	*156*	*160*	*164*	*168*	*171*	*175*	*179*	*183*	*187*
		131	134	137	141	145	149	153	157	162	167	173	179	185	191
32		*137*	*141*	*145*	*149*	*152*	*156*	*160*	*164*	*168*	*171*	*175*	*179*	*183*	*187*
		131	134	137	141	145	149	154	158	163	168	174	180	186	192
33		*137*	*141*	*145*	*149*	*152*	*156*	*160*	*164*	*168*	*171*	*175*	*179*	*183*	*187*
		131	134	137	141	145	149	154	159	164	169	175	181	187	193
34		*138*	*142*	*146*	*150*	*153*	*157*	*161*	*165*	*169*	*172*	*176*	*180*	*184*	*188*
		132	135	138	142	146	150	155	160	165	170	176	182	188	194
35		*139*	*143*	*147*	*151*	*154*	*158*	*162*	*166*	*170*	*173*	*175*	*181*	*185*	*189*
		132	135	138	142	146	150	155	160	165	170	176	182	189	195

[1] *ARMY SEPARATEES*

[2] MEDICO-ACTUARIAL

67. Newman, Russell W. Measurement of Body Fat in Stress Situations. Report No. 193, Environmental Protection Division, Quartermaster Research and Development Command, Natick, Massachusetts, November 1952.

Purpose: "This study was initiated to investigate the use of body fat measurement by the skin-fold technique in environmental stress situations. Two experiments, one involving a prolonged heat exposure, and the other concerned with the consumption of a survival ration furnished the opportunities to collect the data."

Subjects: Heat exposure experiment: N = 5
Survival ration study: N = 10

Apparatus and Procedure: The caliper used to measure the skin-folds is based on the model used by Brozek and Keys and calibrated to give equivalent results. "In the survival ration study the areas of skin-fold measurement were marked by injection of minute amounts of sterile india ink to increase the reliability of day-to-day measurements on the same individuals."

"The (heat) experiment was divided into three phases, a pre-heat control phase lasting for three weeks during which the subjects were kept in an air-conditioned room at approximately 75°F., a heat phase lasting for two weeks in which the men were subjected to 120°F. during the day and 100°F. at night, and a post-heat control period of ten days again at 75°F."

The survival ration study was divided into two phases, "a control phase lasting for 13 days during which the subjects were kept in an air-conditioned chamber at 80°F., and were fed on C rations, and a survival ration phase of ten days in the same room and at approximately the same ambient temperature."

Conclusions: "Data on body fat in the heat study indicated that this measure was influenced by the extreme heat (120°F.) in which the subjects were placed. The high fat values obtained in the heat were presumably caused by a peripheral vasodilation which appeared within the initial four hours of exposure... . In the absence of heat stress, the skin-fold method for estimating body fat gave excellent results, the simplicity of instrumentation and ease of collecting data make this method ideal for investigating military groups under laboratory or field conditions. The analyses presented in this study indicated that the weight loss recorded for the test subjects in both experiments can be closely accounted for in terms of the adipose and protein tissue losses."

This report is 18 pages long and contains two tables and nine figures including photographs portraying the skin-fold caliper and its use. Data from the report are included in this annotation.

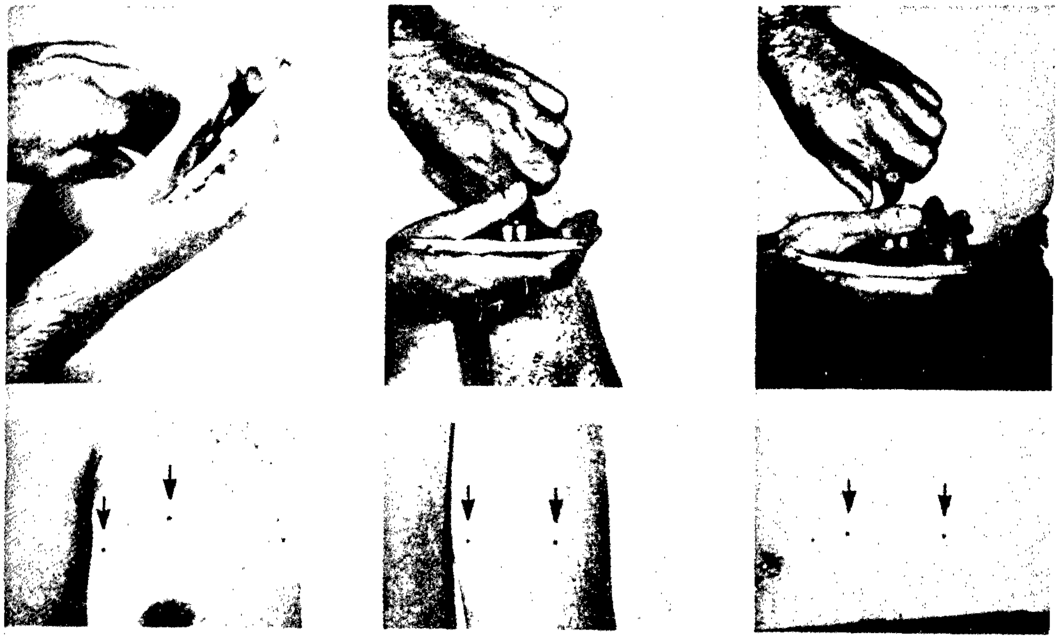


FIGURE 67 - 1

Location and Technique of Skin-Fold Measurements

FIGURE 67 - 2

Skin-Fold Caliper

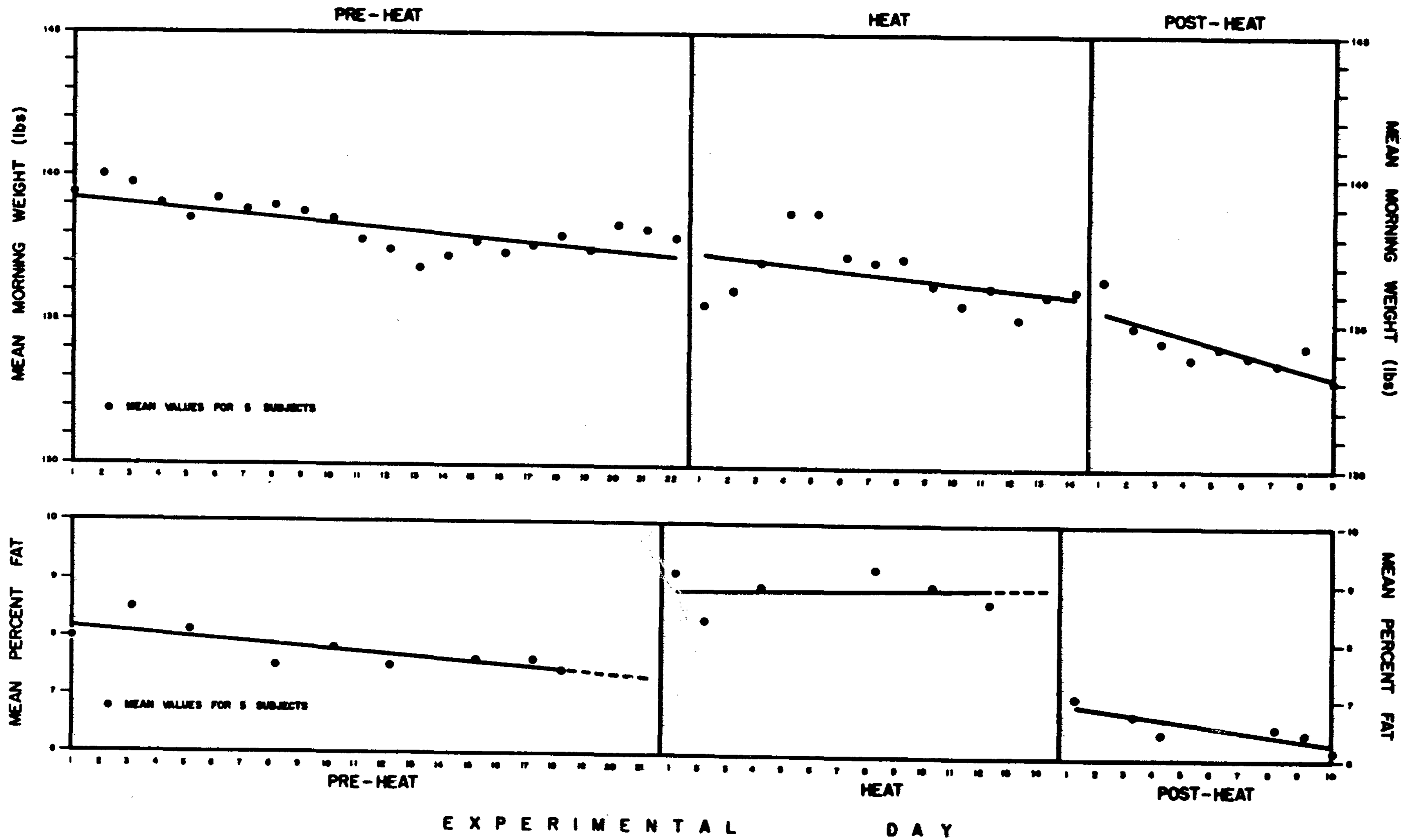


FIGURE 67 - 3

Heat Study, Weight and Fat

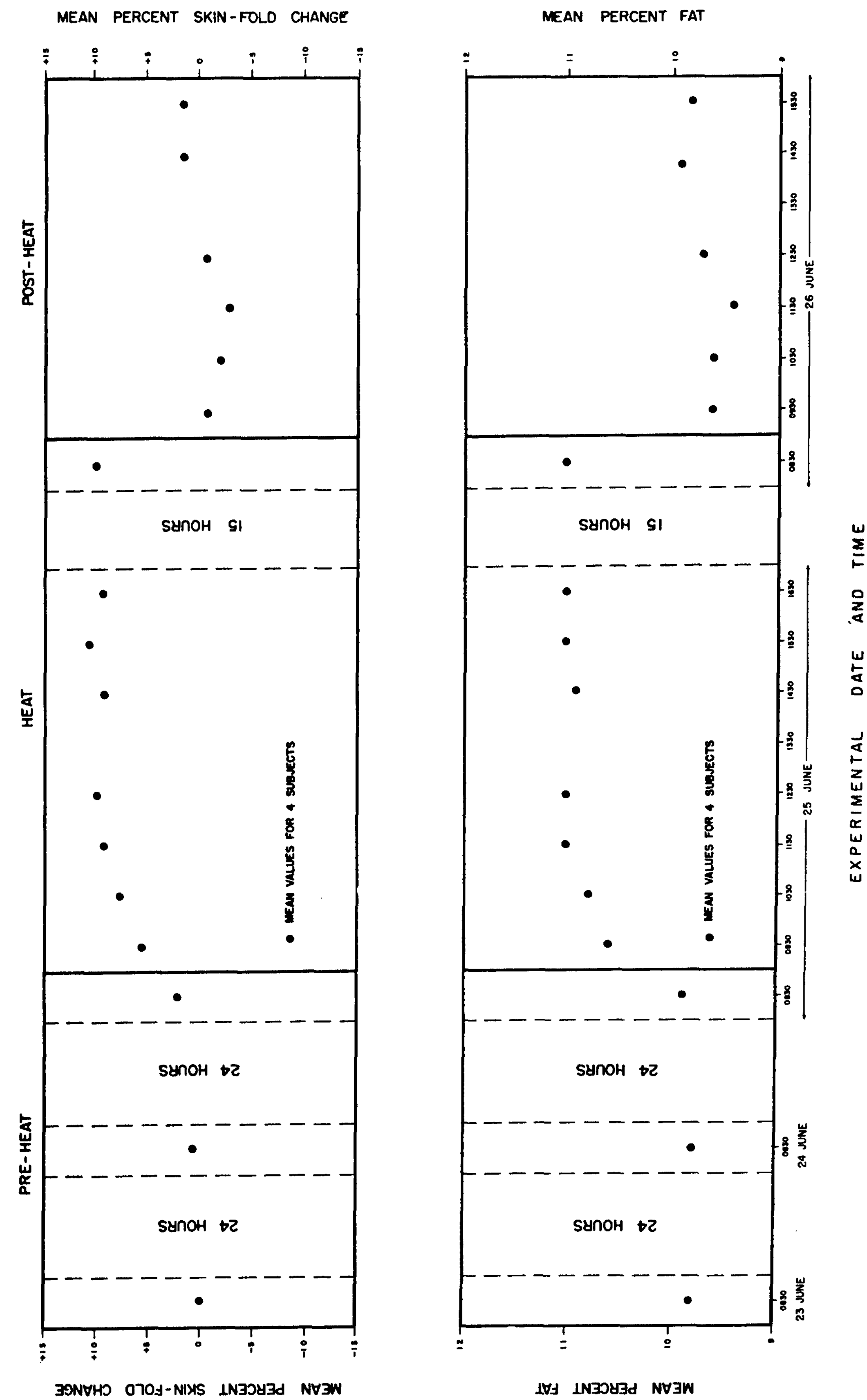


FIGURE 67 - 4

24 Hour Study, Fat and Skin-Fold Change

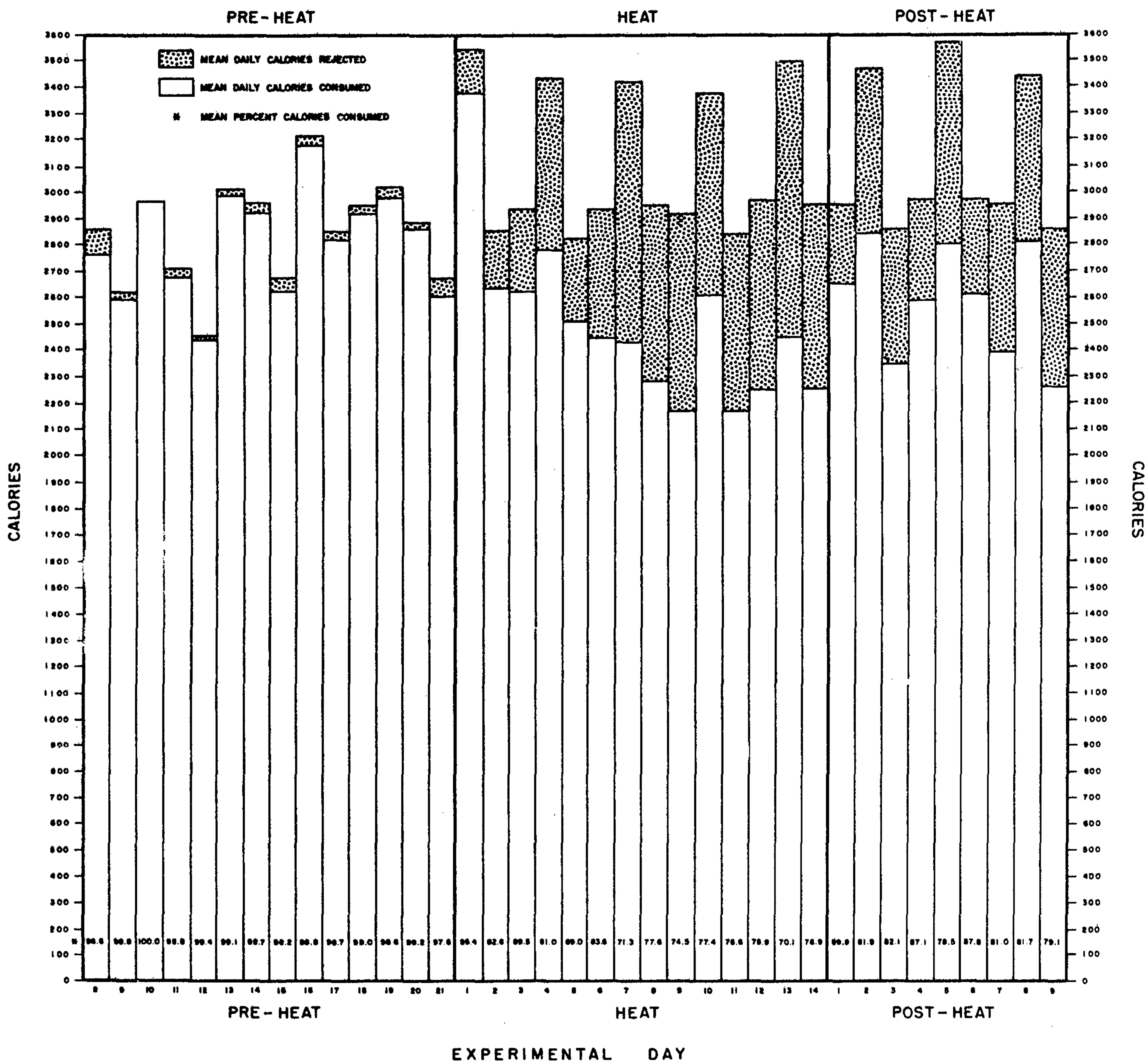


FIGURE 67 - 5

Heat Study, Mean Daily Caloric Intake

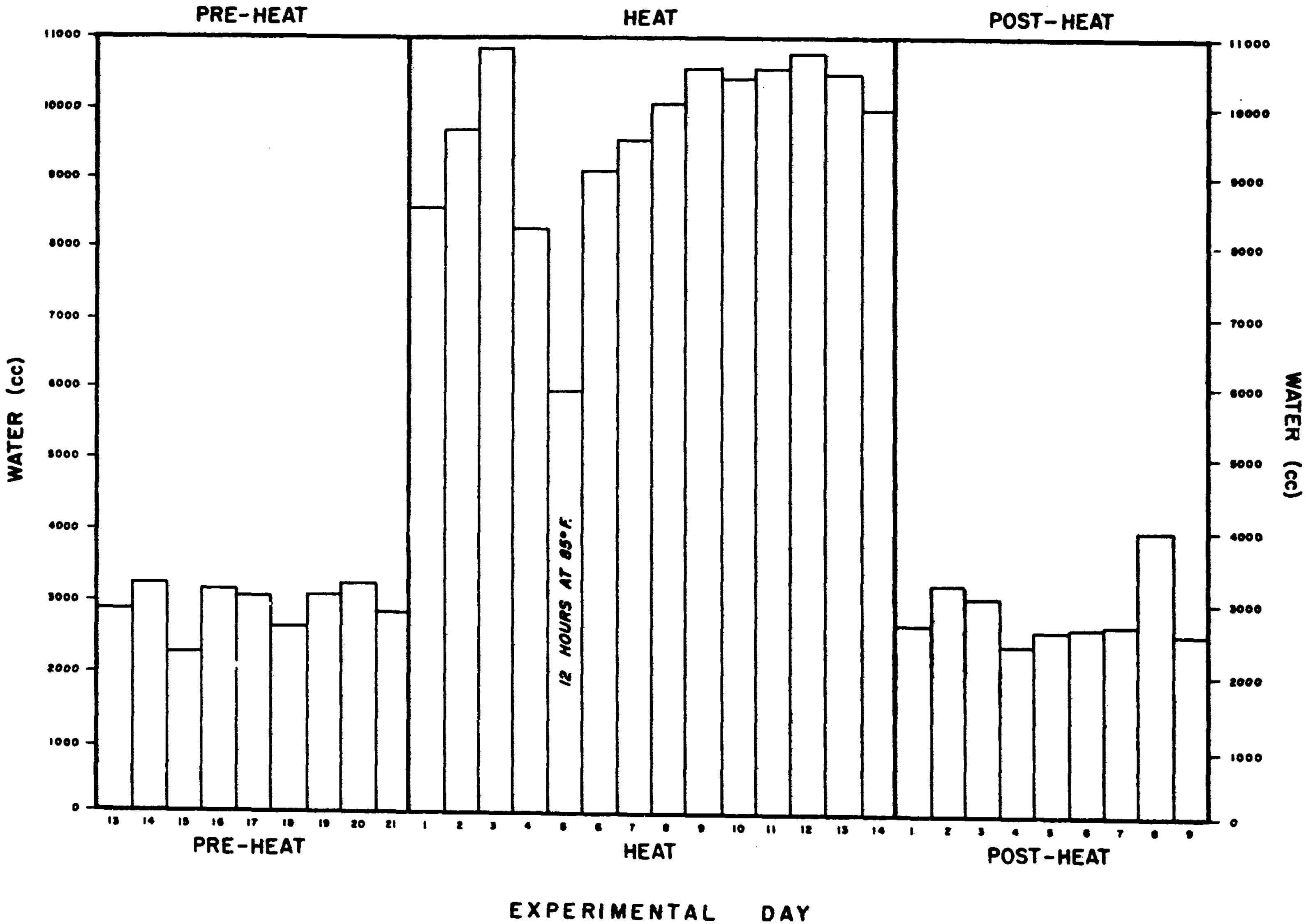


FIGURE 67 - 6

Heat Study, Mean Daily Water Intake

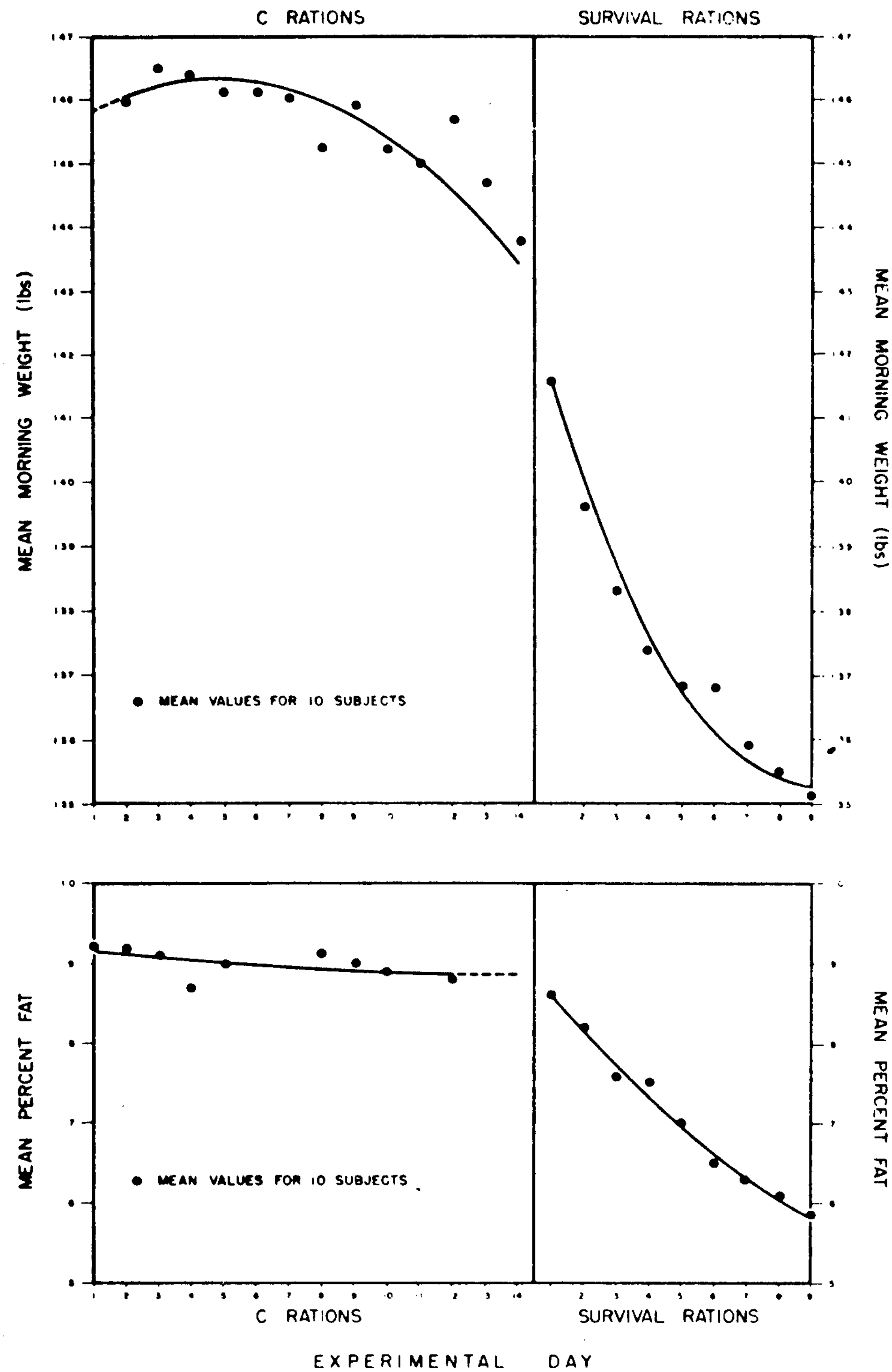


FIGURE 67 - 7

Ration Study, Weight and Fat

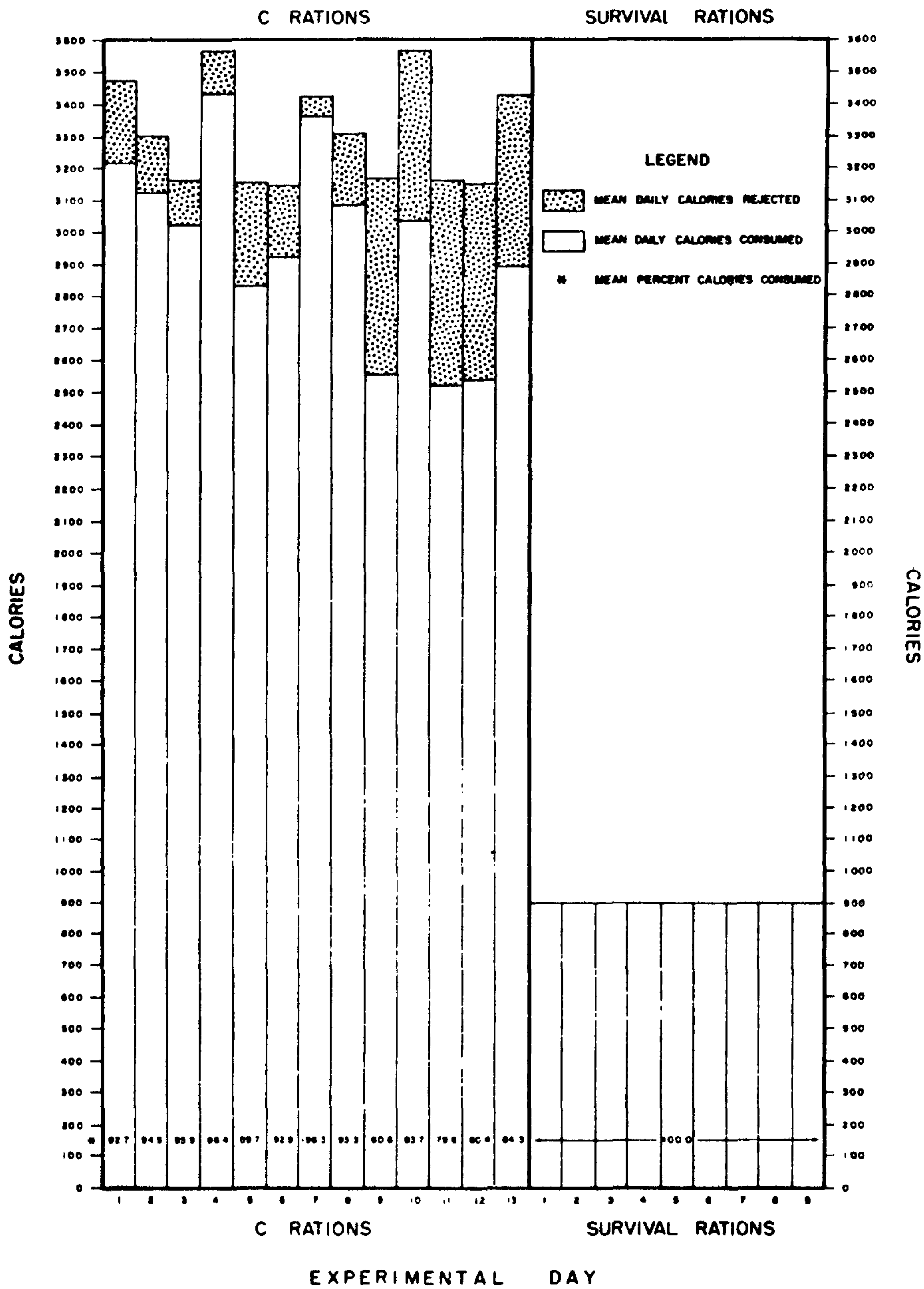


FIGURE 67 - 8

Ration Study, Mean Daily Caloric Intake

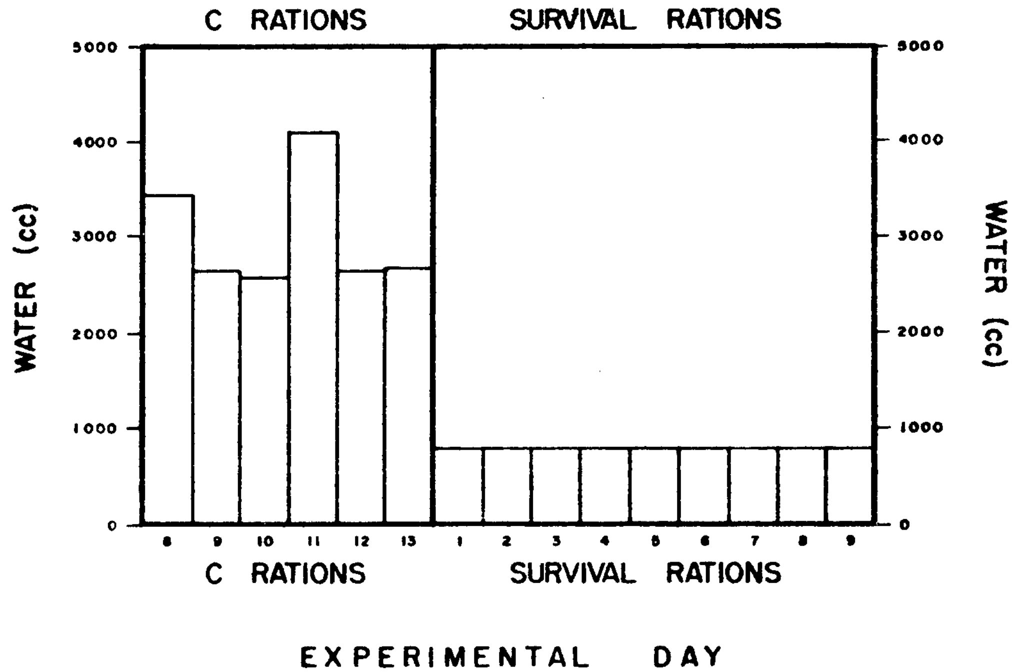


FIGURE 67 - 9

Ration Study, Mean Daily Water Intake

TABLE 67 - 1

Individual Fat Values Obtained in the Heat Study
Expressed as Percent of Body Weight

		Subjects				
	Day	C.L.	T.N.	E.M.	F.H.	H.H.
Pre-Heat	1	4.6	6.2	8.0	10.2	11.2
	3	4.2	6.2	8.4	11.6	12.3
	5	4.1	6.0	8.1	10.7	11.8
	8	3.8	6.0	7.6	9.6	10.4
	10	3.8	6.0	8.4	10.5	10.4
	12	3.6	5.8	8.2	9.2	10.8
	15	3.7	6.1	7.8	10.3	9.9
	17	3.9	6.2	8.5	9.7	9.6
	18	3.6	5.9	7.5	10.1	10.0
Heat	1	5.0	7.2	10.2	11.2	12.0
	2	4.7	7.0	8.4	10.2	11.4
	4	5.1	7.2	8.9	12.2	11.1
	8	5.2	7.2	9.4	11.6	12.6
	10	5.0	6.9	9.3	12.2	10.9
	12	5.0	6.9	9.5	11.0	10.5
Post-Heat	1	3.7	5.4	7.9	9.0	8.8
	3	3.5	5.1	7.4	8.5	8.8
	4	3.3	5.2	6.7	8.4	8.5
	8	3.5	5.1	6.7	8.1	9.3
	9	3.4	5.3	6.9	8.2	8.4
	10	3.4	4.6	7.0	7.5	8.1

TABLE 67 - 2

Individual Fat Values Expressed as Percent of Body Weight Obtained in the Ration Study

	Day	C.C.	J.C.	P.D.	F.G.	E.B.	D.B.	H.W.	E.G.	R.K.	J.W.
		SUBJECTS									
C Rations	1	5.3	6.2	6.2	6.3	7.6	8.7	8.8	10.8	13.1	19.3
	2	5.5	6.0	6.7	6.5	8.0	8.3	8.2	11.1	13.4	18.4
	3	5.3	6.0	6.2	6.8	8.2	8.4	8.6	11.6	12.3	18.0
	4	5.4	6.2	6.0	6.2	7.9	8.1	8.3	10.1	11.7	17.4
	5	5.6	6.0	6.2	6.6	8.0	8.8	8.3	10.5	12.1	18.4
	8	5.5	5.8	6.4	7.0	7.9	8.6	9.2	10.7	13.3	16.7
	9	5.8	5.9	5.5	6.9	7.8	8.4	9.0	11.0	11.6	17.6
	10	5.7	6.0	5.8	6.7	7.8	8.5	8.5	10.7	12.0	17.7
	12	5.3	6.0	6.3	6.9	8.1	8.5	8.8	10.1	11.9	16.4
Survival Rations	1	5.7	5.2	5.6	6.8	7.6	8.1	7.4	10.7	12.0	16.6
	2	5.3	5.4	5.0	6.2	7.5	7.8	7.2	10.1	11.2	16.1
	3	4.6	4.6	4.9	5.5	7.2	7.7	6.8	9.4	10.3	14.9
	4	4.5	4.6	4.8	5.6	6.6	7.3	6.6	9.0	10.9	14.8
	5	4.6	4.4	4.4	5.5	6.3	7.0	6.4	8.2	9.2	14.1
	6	4.3	4.2	4.3	4.9	6.1	6.4	5.6	7.9	8.3	13.0
	7	4.2	3.9	4.1	5.0	6.0	6.4	5.4	8.2	8.2	11.8
	8	3.9	3.8	3.9	4.3	5.6	6.5	5.6	8.0	8.0	11.4
	9	3.8	3.8	3.5	4.2	5.8	6.2	5.0	7.4	7.8	10.7

68. Newman, Russell W. <u>Model and Size Data for the Design of Men's Clothing</u>. Environmental Protection Division, Report No. 217, Natick QM Research and Development Laboratory, Lawrence, Massachusetts, July 1953. (Armed Services Technical Information Agency No. AD-21553.)

"This study presents average data on bodily dimensions of approximately 25,000 U.S. Army soldiers. This series is successively divided into subgroups on the basis of size (Chest Circumference), model (Drop or Chest Circumference minus Waist Circumference), and length (Stature). Mean values on size groups and models within size groups are presented in tabular and graphic form to facilitate interpretation. Length groups within the models and sizes are given in tabular form only. The percentage of occurrence of the model groups, i.e., 25 percent of Slender (seven to ten inches of Drop), 62 percent Normal (four to seven inches of Drop), 10 percent Portly (1-1/2 to four inches of Drop), and 1 percent Stout (zero to 1-1/2 inches of Drop) indicates that a definite requirement exists for their use in men's service or semi-dress uniforms. The atypical groups, Slender and Portly, are found with almost equal frequency in all chest size groups. It is recommended that the data presented here be considered in any proposed major revision of the U.S. Army men's service uniform."

The report is 16 pages long. There are three tables and two figures. Three bibliographical references are given in footnotes. The tables presented provide the main data of the report.

TABLE 68 - 1

Mean Values of 30 Measurements by Chest Size Groups

Size (in.)	X-Small 28-32	Small 32-36	Medium 36-40	Large 40-44
Drop	4.6	5.6	6.0	5.7
Age (yrs.)	22.2	23.4	25.1	26.7
Stature	66.7	68.0	69.0	69.5
Weight (lbs.)	123.4	142.2	164.3	196.3
Chest Circumference	31.6	34.7	37.8	41.8
Waist Circumference	27.0	29.1	31.8	36.1
Hip Circumference	33.5	35.5	37.7	40.8
Neck Circumference	13.5	14.1	14.8	15.5
Outseam	40.4	41.2	41.9	42.3
Inseam	32.1	32.7	33.0	33.1
Rise	8.3	8.5	8.9	9.2
Cervical Height	57.2	58.3	59.2	59.9
Sitting Height	34.9	35.5	36.0	36.3
Sleeve Length	30.5	31.4	32.3	32.9
Trunk Height	22.3	22.8	23.2	23.6
Total Crotch Length	26.5	27.7	29.1	31.3
Shoulder Length	5.7	5.9	6.1	6.2
Bideltoid	16.5	17.4	18.4	19.6
Bi-Iliac	10.8	11.2	11.7	12.5
Chest Breadth	10.1	10.8	11.5	12.4
Chest Depth	7.6	8.0	8.6	9.5
Cross Back Width	13.6	14.4	15.2	16.2
Hip Breadth	12.9	13.5	14.3	15.4
Trunk Depth	8.0	8.6	9.4	10.5
Crotch Thigh Circumference	19.0	20.4	22.1	24.4
Mid Thigh Circumference	17.4	18.5	19.8	21.3
Arm Scye	15.5	16.6	17.6	18.8
Axillary Arm Circumference	10.7	11.6	12.5	13.8
Mid Upper Arm Circumference	9.7	10.5	11.4	12.6
Upper Forearm Circumference	9.6	10.2	10.8	11.5
Percentage Frequency	2.1	47.9	44.2	3.9

TABLE 68 - 2

Mean Values of 30 Measurements by Size and Model Groups

Size (in.)	X-Small 28-32				Small 32-36				Medium 36-40				Large 40-44			
Model (in.)	Slender 7-10	Normal 4-7	Portly 1-1/2-4	Stout 0-1-1/2	Slender 7-10	Normal 4-7	Portly 1-1/2-4	Stout 0-1-1/2	Slender 7-10	Normal 4-7	Portly 1-1/2-4	Stout 0-1-1/2	Slender 7-10	Normal 4-7	Portly 1-1/2-4	Stout 0-1-1/2
Drop		5.1	3.0		7.6	5.5	3.0	0.6	7.9	5.5	2.9	0.6	8.2	5.4	2.8	0.4
Age (yrs.)		22.1	22.7		22.6	23.4	25.3	26.8	23.7	25.4	27.5	29.0	25.4	26.9	28.5	27.5
Stature		66.7	66.7		68.2	68.0	67.9	67.4	69.0	69.0	68.7	68.5	69.6	69.5	69.6	69.0
Weight (lbs.)		122.0	128.6		137.6	142.4	149.2	149.4	157.5	165.9	175.3	183.7	186.6	197.4	208.0	213.7
Chest Circumference		31.6	31.5		35.1	34.7	34.6	34.7	37.8	37.7	38.0	38.5	41.7	41.7	42.0	41.7
Waist Circumference		26.5	28.6		27.4	29.2	31.6	34.1	29.9	32.2	35.1	37.9	35.5	36.3	39.2	41.3
Hip Circumference		33.4	34.1		34.8	35.6	36.5	36.1	36.8	37.9	39.0	39.3	39.7	41.0	42.0	42.2
Neck Circumference		13.6	13.7		14.0	14.1	14.3	14.3	14.6	14.8	15.0	15.3	15.3	15.5	15.8	15.7
Outseam		40.3	40.5		41.3	41.2	41.3	41.0	41.9	41.9	41.8	41.8	42.4	42.2	42.6	42.0
Inseam		32.0	32.2		32.7	32.7	32.7	32.4	33.1	33.0	32.8	32.7	33.3	33.1	33.0	32.8
Rise		8.2	8.3		8.6	8.5	8.6	8.5	8.8	8.9	9.0	9.1	9.1	9.2	9.6	9.2
Cervical Height		57.2	57.2		58.4	58.3	58.2	57.8	59.2	59.2	59.1	58.8	59.8	59.9	60.0	59.6
Sitting Height		34.9	34.8		35.7	35.5	35.4	35.2	36.1	36.0	35.8	35.6	36.3	36.2	36.4	36.2
Sleeve Length		30.4	30.8		31.5	31.4	31.4	31.1	32.3	32.2	32.1	31.9	32.9	32.9	32.9	32.2
Trunk Height		22.4	21.8		23.0	22.8	22.7	22.4	23.2	23.2	23.2	23.1	23.7	23.5	23.7	23.3
Total Crotch Length		26.4	27.0		27.4	27.7	28.3	28.2	28.6	29.2	30.1	30.8	30.6	31.4	32.0	32.3
Shoulder Length		5.8	5.7		6.0	6.0	5.8	5.9	6.2	6.1	6.0	6.0	6.3	6.2	6.2	6.2
Bideltoid		16.5	16.7		17.4	17.4	17.5	17.6	18.2	18.4	18.6	18.9	19.5	19.6	19.9	20.2
Bi-Iliac		10.6	10.9		11.0	11.2	11.4	11.4	11.5	11.7	12.0	12.3	12.2	12.5	12.8	13.0
Chest Breadth		10.0	10.2		10.8	10.7	10.8	10.8	11.5	11.5	11.6	11.6	12.3	12.4	12.4	12.1
Chest Depth		7.5	7.8		8.1	8.0	8.1	8.1	8.5	8.6	8.8	9.0	9.3	9.6	9.7	9.5
Cross Back Width		13.6	13.9		14.4	14.4	14.5	14.4	15.1	15.2	15.3	15.5	16.1	16.2	16.5	16.0
Hip Breadth		12.9	13.1		13.3	13.5	13.6	13.7	14.0	14.3	14.7	14.9	15.0	15.4	15.8	16.1
Trunk Depth		8.0	7.9		8.6	8.6	8.4	8.5	9.2	9.4	9.6	10.1	10.3	10.5	11.0	11.6
Crotch Thigh Circumference		18.8	19.6		19.9	20.5	21.2	20.8	21.5	22.3	23.1	23.6	23.8	24.5	25.0	25.3
Mid Thigh Circumference		17.3	17.8		18.2	18.5	19.0	19.0	19.4	19.9	20.4	20.9	20.8	21.4	21.7	22.5
Arm Scye		15.4	15.8		16.4	16.6	16.8	16.8	17.4	17.6	17.9	18.2	18.6	18.8	19.1	19.2
Axillary Arm Circumference		10.0	11.0		11.3	11.6	12.1	12.0	12.2	12.6	13.1	13.3	13.5	13.8	14.2	14.3
Mid Upper Arm Circumference		9.6	10.0		10.4	10.6	10.9	10.9	11.2	11.5	11.6	12.2	12.5	12.6	12.8	12.8
Upper Forearm Circumference		9.5	9.7		10.1	10.2	10.4	10.3	10.6	10.8	11.0	11.2	11.3	11.5	11.7	11.9
Percentage Frequency	(0.1)	1.7	0.5	(0.1)	9.0	34.2	4.3	0.3	15.0	24.1	4.5	0.7	1.2	1.9	0.6	0.1

(a)

TABLE 68 - 2 (Continued)

Model (in.)	Slender 7-10				Normal 4-7				Portly 1-1/2 - 4				Stout 0 - 1-1/2			
Size (in.)	XS 28-32	S 32-36	M 36-40	L 40-44	XS 28-32	S 32-36	M 36-40	L 40-44	XS 28-32	S 32-36	M 36-40	L 40-44	XS 28-32	S 32-36	M 36-40	L 40-44
Drop		7.6	7.9	8.2	5.1	5.5	5.5	5.4	3.0	3.0	2.9	2.8		0.6	0.6	0.4
Age (yrs.)		22.6	23.7	25.4	22.1	23.4	25.4	26.9	22.7	25.3	27.5	28.5		26.8	29.0	27.5
Stature		68.2	69.0	69.6	66.7	68.0	69.0	69.5	66.7	67.9	68.7	69.6		67.4	68.5	69.0
Weight (lbs.)		137.6	157.5	186.6	122.0	142.4	165.9	197.4	128.6	149.2	175.3	208.0		149.4	183.7	213.7
Chest Circumference		35.1	37.8	41.7	31.6	34.7	37.7	41.7	31.5	34.6	38.0	42.0		34.7	38.5	41.7
Waist Circumference		27.4	29.9	33.5	26.5	29.2	32.2	36.3	28.6	31.6	35.1	39.2		34.1	37.9	41.3
Hip Circumference		34.8	36.8	39.7	33.4	35.6	37.9	41.0	34.1	36.5	39.0	42.0		36.1	39.3	42.2
Neck Circumference		14.0	14.6	15.3	13.6	14.1	14.8	15.5	13.7	14.3	15.0	15.8		14.3	15.3	15.7
Outseam		41.3	41.9	42.4	40.3	41.2	41.9	42.2	40.5	41.3	41.8	42.6		41.0	41.8	42.0
Inseam		32.7	33.1	33.3	32.0	32.7	33.0	33.1	32.2	32.7	32.8	33.0		32.4	32.7	32.8
Rise		8.6	8.8	9.1	8.2	8.5	8.9	9.2	8.3	8.6	9.0	9.6		8.5	9.1	9.2
Cervical Height		58.4	59.2	59.8	57.2	58.3	59.2	59.9	57.2	58.2	59.1	60.0		57.8	58.8	59.6
Sitting Height		35.7	36.1	36.3	34.9	35.5	36.0	36.2	34.8	35.4	35.8	36.4		35.2	35.6	36.2
Sleeve Length		31.5	32.3	32.9	30.4	31.4	32.2	32.9	30.8	31.4	32.1	32.9		31.1	31.9	32.2
Trunk Height		23.0	23.2	23.7	22.4	22.8	23.2	23.5	21.8	22.7	23.2	23.7		22.4	23.1	23.3
Total Crotch Length		27.4	28.6	30.6	26.4	27.7	29.2	31.4	27.0	28.3	30.1	32.0		28.2	30.8	32.3
Shoulder Length		6.0	6.2	6.3	5.8	6.0	6.1	6.2	5.7	5.8	6.0	6.2		5.9	6.0	6.2
Bideltoid		17.4	18.2	19.5	16.5	17.4	18.4	19.6	16.7	17.5	18.6	19.9		17.6	18.9	20.2
Bi-Iliac		11.0	11.5	12.2	10.6	11.2	11.7	12.5	10.9	11.4	12.0	12.8		11.4	12.3	13.0
Chest Breadth		10.8	11.5	12.3	10.0	10.7	11.5	12.4	10.2	10.8	11.6	12.4		10.8	11.6	12.1
Chest Depth		8.1	8.5	9.3	7.5	8.0	8.6	9.6	7.8	8.1	8.8	9.7		8.1	9.0	9.5
Cross Back Width		14.4	15.1	16.1	13.6	14.4	15.2	16.2	13.9	14.5	15.3	16.5		14.4	15.5	16.0
Hip Breadth		13.3	14.0	15.0	12.9	13.5	14.3	15.4	13.1	13.8	14.7	15.8		13.7	14.9	16.1
Trunk Depth		8.6	9.2	10.3	8.0	8.6	9.4	10.5	7.9	8.4	9.6	11.0		8.5	10.1	11.6
Crotch Thigh Circumference		19.9	21.5	23.8	18.8	20.5	22.3	24.5	19.6	21.2	23.1	25.0		20.8	23.6	25.3
Mid Thigh Circumference		18.2	19.4	20.8	17.3	18.5	19.9	21.4	17.8	19.0	20.4	21.7		19.0	20.9	22.5
Arm Scye		16.4	17.4	18.6	15.4	16.6	17.6	18.8	15.8	16.8	17.9	19.1		16.8	18.2	19.2
Axillary Arm Circumference		11.3	12.2	13.5	10.6	11.6	12.6	13.8	11.0	12.1	13.1	14.2		12.0	13.3	14.3
Mid Upper Arm Circumference		10.4	11.2	12.3	9.6	10.6	11.5	12.6	10.0	10.9	11.8	12.8		10.9	12.2	12.8
Upper Forearm Circumference		10.1	10.6	11.3	9.5	10.2	10.8	11.5	9.7	10.4	11.0	11.7		10.3	11.2	11.9
Percentage Frequency	(0.1)	9.0	15.0	1.2	1.7	34.2	24.1	1.9	0.5	4.3	4.5	0.6	(0.1)	0.3	0.7	0.1

(b)

TABLE 68 - 3

Mean Values of 14 Measurements by Size, Model, and Length Groups

Size (in.)	X-Small 28-32											
Model (in.)	Slender 7-10			Normal 4-7			Portly 1-1/2 - 4			Stout 0 - 1-1/2		
Length (in.)	S 63-67	R 67-71	L 71-75	S 63-67	R 67-71	L 71-75	S 63-67	R 67-71	L 71-75	S 63-67	R 67-71	L 71-75
Drop				5.1	5.2	5.2	3.0	2.9				
Age (yrs.)				21.9	22.2	21.8	22.9	21.8				
Stature				65.2	68.5	71.9	65.0	68.7				
Weight (lbs.)				118.4	124.9	130.7	123.3	134.3				
Chest Circumference				31.6	31.7	31.6	31.4	31.6				
Waist Circumference				26.5	26.5	26.4	28.4	28.7				
Outseam				39.3	41.4	43.4	39.3	41.9				
Inseam				31.2	33.0	34.7	31.2	33.3				
Rise				8.1	8.4	8.7	8.1	8.6				
Cervical Height				55.8	58.7	61.2	55.7	58.9				
Sitting Height				34.3	35.8	36.8	34.3	35.6				
Sleeve Length				29.7	31.2	32.4	29.9	31.9				
Trunk Height				21.8	23.0	23.3	22.1	22.7				
Total Crotch Length				26.0	26.8	27.5	26.8	27.2				
Percentage Frequency	-----	(0.1)	-----	0.8	0.7	0.1	0.2	0.2	(0.03)	-----	(0.1)	-----

S: Short R: Regular L: Long

TABLE 68 - 3 (Continued

Size (in.)	Large 40-44											
Model (in.)	Slender 7-10			Normal 4-7			Portly 1-1/2 - 4			Stout C - 1-1/2		
Length (in.)	S 63-67	R 67-71	L 71-75	S 63-67	R 67-71	L 71-75	S 63-67	R 67-71	L 71-75	S 63-67	R 67-71	L 71-75
Drop	8.1	8.2	8.2	5.4	5.4	5.5	2.7	2.8	2.8		0.5	
Age (yrs.)	25.6	25.8	24.8	26.8	26.8	27.0	29.7	27.3	30.1		27.7	
Stature	65.9	69.1	72.3	65.8	69.0	72.0	65.7	69.2	72.3		68.8	
Weight (lbs.)	178.2	185.9	191.4	185.8	195.6	207.0	191.5	207.9	217.4		213.1	
Chest Circumference	41.7	41.8	41.6	41.8	41.7	41.8	41.8	42.0	42.1		41.6	
Waist Circumference	33.6	33.6	33.4	36.4	36.3	36.3	39.1	39.2	39.3		41.1	
Outseam	39.9	41.9	44.3	39.7	41.9	43.8	40.0	42.5	44.2		41.8	
Inseam	31.0	33.0	34.9	30.9	32.8	34.5	31.0	32.8	34.6		32.6	
Rise	8.9	8.9	9.4	8.8	9.1	9.3	9.0	9.7	9.6		9.2	
Cervical Height	56.2	59.5	62.3	56.6	59.4	62.1	56.8	59.7	62.3		59.5	
Sitting Height	34.9	36.1	37.2	35.5	36.0	37.2	34.9	36.2	37.3		36.0	
Sleeve Length	31.5	32.7	33.8	31.5	32.8	33.6	31.2	32.7	34.1		32.0	
Trunk Height	22.7	23.6	24.3	22.5	23.3	24.3	22.7	23.7	24.3		23.4	
Total Crotch Length	30.3	30.6	30.9	31.0	31.3	31.9	31.9	32.0	33.1		32.4	
Percentage Frequency	0.2	0.7	0.3	0.2	1.2	0.4	0.1	0.4	0.2	(0.01)	0.1	(0.03)

TABLE 68 - 3 (Continued)

Size (in.)	Medium 36-40											
Model (in.)	Slender 7-10			Normal 4-7			Portly 1-1/2 - 4			Stout 0 - 1-1/2		
Length (in.)	S 63-67	R 67-71	L 71-75	S 63-67	R 67-71	L 71-75	S 63-67	R 67-71	L 71-75	S 63-67	R 67-71	L 71-75
Drop	8.0	7.9	8.0	5.4	5.5	5.6	2.8	2.9	3.0	0.5	0.6	0.7
Age (yrs.)	24.3	23.6	23.3	26.3	25.3	24.8	28.3	27.5	26.2	29.0	28.8	29.4
Stature	65.7	68.9	72.1	65.8	68.9	72.2	65.6	68.9	72.2	65.6	68.8	72.1
Weight (lbs.)	148.7	157.1	165.7	157.1	165.5	175.1	166.0	175.5	186.1	174.6	183.8	199.5
Chest Circumference	37.7	37.8	38.0	37.6	37.7	37.9	37.8	38.0	38.2	38.4	38.5	38.7
Waist Circumference	29.7	29.9	30.0	32.2	32.2	32.3	35.0	35.1	35.2	37.9	37.9	38.0
Outseam	39.6	41.8	43.9	39.7	41.9	44.1	39.7	42.0	44.0	39.8	42.0	44.3
Inseam	31.2	33.0	34.9	31.1	33.0	34.9	30.9	32.9	34.8	31.1	32.8	35.0
Rise	8.4	8.8	9.0	8.6	8.9	9.2	8.8	9.1	9.2	8.7	9.2	9.3
Cervical Height	56.3	59.2	62.0	56.4	59.2	62.1	56.3	59.3	62.3	56.4	59.2	62.0
Sitting Height	34.8	36.0	37.2	34.7	35.9	37.2	34.6	35.9	37.1	34.6	35.9	36.0
Sleeve Length	31.0	32.3	33.6	30.9	32.2	33.6	30.8	32.2	33.3	30.8	31.9	33.8
Trunk Height	22.3	23.2	24.1	22.4	23.2	24.0	22.4	23.2	24.1	22.5	23.2	23.4
Total Crotch Length	27.9	28.6	29.1	28.7	29.1	29.7	29.8	30.1	30.5	30.5	30.9	30.4
Percentage Frequency	2.7	8.9	3.1	4.7	14.1	4.9	1.0	2.6	0.8	0.2	0.4	0.1

TABLE 68 - 3 (Continued)

Size (in.)	Small 32-36											
Model (in.)	Slender 7-10			Normal 4-7			Portly 1-1/2 - 4			Stout 0 - 1-1/2		
Length (in.)	S 63-67	R 67-71	L 71-75	S 63-67	R 67-71	L 71-75	S 63-67	R 67-71	L 71-75	S 63-67	R 67-71	L 71-75
Drop	7.7	7.6	7.6	5.4	5.5	5.5	3.1	3.0	3.0	0.4	0.7	
Age (yrs.)	22.7	22.7	22.3	23.8	23.2	22.9	25.5	25.2	24.8	27.6	26.5	
Stature	65.6	68.8	72.0	65.5	68.7	72.0	65.5	68.7	72.1	65.3	68.4	
Weight (lbs.)	131.4	139.1	146.4	135.8	144.5	153.2	142.8	151.6	160.1	142.3	154.8	
Chest Circumference	34.9	35.1	35.2	34.4	34.7	34.9	34.4	34.7	34.8	34.7	34.7	
Waist Circumference	27.2	27.5	27.6	29.0	29.2	29.4	31.3	31.7	31.8	34.3	34.0	
Outseam	39.5	41.7	43.9	39.5	41.7	44.0	39.6	41.9	43.9	39.2	41.8	
Inseam	31.2	33.1	34.9	31.2	33.1	35.1	31.3	33.2	35.3	31.1	33.0	
Rise	8.3	8.6	9.0	8.3	8.6	8.9	8.3	8.7	8.6	8.1	8.8	
Cervical Height	56.0	59.0	62.0	56.0	59.0	61.8	56.0	59.0	62.2	55.9	58.8	
Sitting Height	34.7	35.9	37.3	34.6	35.8	37.0	34.5	35.7	37.0	34.3	35.7	
Sleeve Length	30.4	31.8	32.9	30.4	31.8	33.1	30.4	31.9	33.3	29.5	31.8	
Trunk Height	22.3	23.2	24.1	22.1	23.0	23.8	22.1	22.9	23.6	21.7	22.8	
Total Crotch Length	26.8	27.4	28.2	27.3	27.9	28.4	28.0	28.5	28.7	27.7	28.7	
Percentage Frequency	2.6	5.1	1.2	11.0	18.6	3.9	1.4	2.2	0.5	0.1	0.2	(0.03)

69. Newman, Russell W. and Robert M. White. Reference Anthropometry of Army Men. Environmental Protection Division, Report No. 180, Quartermaster Research and Development Center, Natick, Massachusetts, September 1951.

Eighty-seven regression tables and seventy-eight bivariate charts are presented in this report to indicate a wide variety of interrelationships of pairs of dimensions which exist for a sample population of men in the army. These data should serve as a guide to the designers of equipment for use by Army men.

Body size data for 65 measurements of 25,000 Army males were obtained for use by designers of clothing and equipment intended for men in the army. These data were derived from an anthropometric survey conducted by the Quartermaster Corps in 1946. Approximately 85,000 U.S. Army white males were measured in the survey.

"The men measured in this survey had been in military service for varying lengths of time. They represented a sample of men who were not only segregated by the process of military selection, but also exposed to a military environment. This group is thus not necessarily representative of civilian groups of comparable size and age distribution. Men entering the service and the potential pool of manpower from which the services draw may differ somewhat in the distribution of body sizes and bodily proportions. The men reported here were all measured as they were processed through separation centers at the close of World War II. They were civilian soldiers returning to civilian life and may not accurately reflect the peacetime population of the Regular Army."

"The data derived from the total sample of approximately 85,000 white males proved too unwieldy and time-consuming to handle in the mechanical processes of sorting and analyzing. For this reason the analyses presented here are based on a smaller sample. It has been found that a geographically weighted subsample of approximately 25,000 white males did not differ significantly from the larger sample. Furthermore, the smaller series allows for a close approximation to the Selective Service data for geographical distribution of birthplace for men examined between November 1940 and June 1945. Thus, the 25,000 subsample should give a close approximation to the military population at the end of World War II."

The age range of the subjects was from 15 to 40+ years, with 92.16% falling in the 18-31 year range.

The regression tables and bivariates include such data as the relationship of chest circumference to arm scye, axillary arm circumference, bideltoid, buttock-knee, cervicale height, cross back width, crotch thigh circumference, elbow breadth, forearm-hand length, hip breadth, hip circumference, inseam, lower leg length, lower upper arm circumference, neck circumference, outseam, patella height, shoulder circumference, shoulder-elbow, sitting height, sleeve lenght, stature, total crotch length, trunk height, vertical trunk circumference, waist circumference, weight, wrist circumference. A total of 43 dimensions are considered in varying detail.

A discussion of the statistics utilized is included in the report, whose 172 pages are primarily tables of data. No bibliography references are included.

See also: Quartermaster Corps, U.S. Army. Survey of Body Size of Army Personnel, Male and Female (1946): Body Dimensions of Army Males. Project No. E-59-46, Environmental Protection Section, Quartermaster Research and Development Center, Natick, Massachusetts.

Randall, F.E. Anthropometric Nomograph of Army White Men.

Randall, F.E., and Baer, M.J. Survey of Body Size of Army Personnel, Male and Female. Phase I, Report No. 1: Methodology. Climatic Research Laboratory, Office of the Quartermaster General, Lawrence, Mass., 1947.

Munro, Ella H. Anthropometric Nomographs. Enviromental Protection Section Report No. 184, Research and Development Branch, (US) Quartermaster Corps, February 1952, 19 p.

70. Newman, Russell W. and Gerald Winston. Comparison of Ten Anthropometric and Tailoring Measures on the Same Men. Environmental Protection Division, Report No. 210, Quartermaster Research and Development Command, Natick, Massachusetts, June 1953.

"This study was undertaken to determine the relationship between two types of measurements, i.e., anthropometric and tailoring. The information could then be applied to the large amount of anthropometric data available on military personnel and would facilitate a translation of anthropometric data into meaningful pattern measurements. Data on ten bodily measurements: neck, shoulder, chest, waist, and hip (seat) circumference, sleeve length, scye depth, inside arm length, outseam, and inseam were presented and analyzed for the relationship between the two types of measurements on 42 men. The relative reliability of the two techniques was assessed and was found to be roughly similar and the relationships appeared sufficiently consistent to warrant translation from one technique to the other without undue loss of accuracy. Methods for conversion from one type of measurement to the other were presented in several forms if appropriate to individual situation."

Method of Calculation: If the anthropometric measurement of scye depth is known (6.9, for example), then the tailoring measure of scye depth can be estimated by inserting the anthropometric value in the appropriate regression equation, thus:

$$\begin{aligned} \text{scye depth (tailoring)} &= 0.620\ (6.9) + 5.133 \pm 0.455 \\ &= 4.278 + 5.133 \pm 0.455 \\ &= 9.411 \pm 0.455 \end{aligned}$$

The tailoring measure of scye depth is therefore estimated to be 9.411, within the probability limits indicated by its standard error (0.445). To determine the anthropometric value from the corresponding tailoring measure, reverse the procedure. (All measurements in Table 70 - 2 are in inches.)

This report is eleven pages long and contains five tables and one figure. One bibliographic reference appears as a footnote. The tables i..cluded in this annotation provide the main data of the report.

TABLE 70 - 1

Correlation Coefficients of Anthropometric and Tailoring

Dimensions	r	Dimensions	r
Waist Circumference	+.983	Outseam Length	+.953
Hip Circumference	+.977	Chest Circumference	+.950
Inseam Length	+.968	Inside Arm Length	+.940
Neck Circumference	+.963	Shoulder Circumference	+.904
Sleeve Length	+.957	Scye Depth	+.599

TABLE 70 - 2

Regression Equations

Equations for Calculating Tailoring from Anthropometric

Waist Circumference	= 0.906	(Anthropometric)	+2.891	±0.517
Hip (Seat) Circumference	= 0.918	(Anthropometric)	+6.627	±0.515
Inseam Length	= 0.898	(Anthropometric)	+1.399	±0.338
Neck Circumference	= 0.952	(Anthropometric)	+1.074	±0.181
Sleeve Length	= 0.906	(Anthropometric)	+2.295	±0.389
Outseam Length	= 0.912	(Anthropometric)	+3.395	±0.514
Chest Circumference	= 0.832	(Anthropometric)	+8.107	±0.618
Inside Arm Length	= 0.874	(Anthropometric)	+1.476	±0.307
Shoulder Circumference	= 0.904	(Anthropometric)	+4.999	±0.405
Scye Depth	= 0.620	(Anthropometric)	+5.133	±0.445

Equations for Calculating Anthropometric from Tailoring

Waist Circumference	= 1.066	(Tailoring)	-2.025	±0.560
Hip (Seat) Circumference	= 1.040	(Tailoring)	-5.225	±0.548
Inseam Length	= 1.044	(Tailoring)	+0.534	±0.364
Neck Circumference	= 0.974	(Tailoring)	+0.004	±0.183
Sleeve Length	= 1.010	(Tailoring)	+0.401	±0.410
Outseam Length	= 0.996	(Tailoring)	+0.402	±0.538
Chest Circumference	= 1.034	(Tailoring)	-5.173	±0.705
Inside Arm Length	= 1.011	(Tailoring)	+0.576	±0.330
Shoulder Circumference	= 1.056	(Tailoring)	-3.293	±0.438
Scye Depth	= 0.579	(Tailoring)	+1.454	±0.430

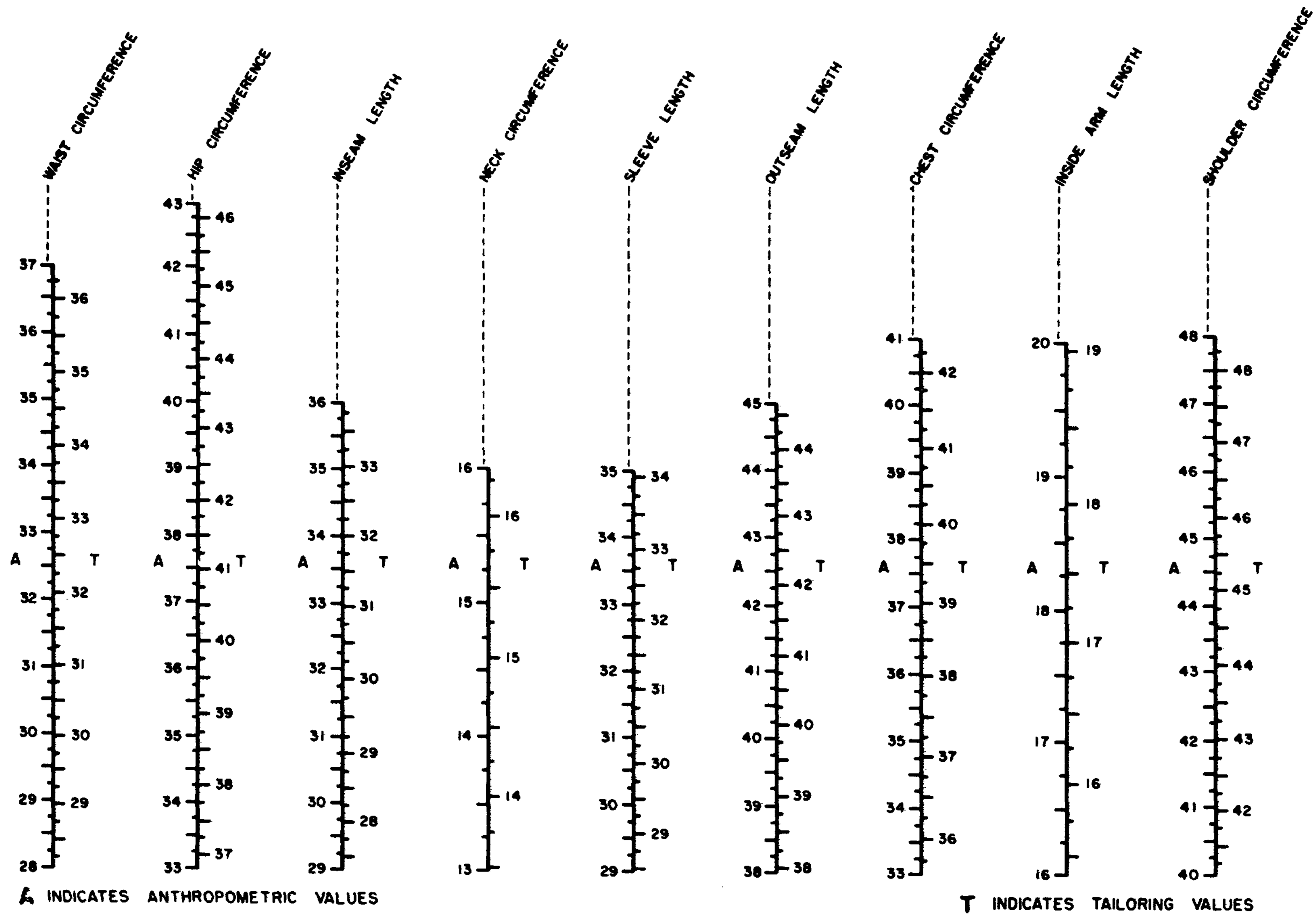


FIGURE 70 - 1

Graphic Correspondence of Anthropometric and Tailoring Dimensions

71. Pere, Soini, Mikko Kunnas, and Antti Telkka. Correlation Between Performance and Physique in Finnish Athletes. American Journal of Physical Anthropology, New Series, Volume 12, No. 2, June 1954, pages 201-208.

"The present paper examines the correlations between the performance and the physique of Finnish track and field athletes. The subjects used for the study were 172 track and field athletes selected from top-ranking sportsmen. The best athletic achievements of each athlete were used as the standard, converted into points according to the International Scoring Table. The achievements in different events are then comparable to each other. The main results are given below:

(1) Throwers were the tallest in this material and they seemed also to benefit most from their height.

(2) The correlation between relative upper limb length and performance was significant in throwers and long distance runners.

(3) The correlation between relative shoulder breadth and performance was negative and highly significant in throwers.

(4) The correlation between relative chest circumference and performance was negative and highly significant in sprinters and positive and significant in throwers.

The correlations between the measure taken of our subjects and the corresponding athletic abilities are few and thus could indicate that the physique does not affect the athletic performance."

The article is seven pages long and includes one table, which is reproduced herewith. The bibliography includes 14 references.

72. Randall, Francis E. Age Changes in Young Adult Army Males. Human Biology, Volume 21, 1949, pp. 187-198.

The purpose of this study is to determine whether or not young men of ages 17, 18, and 19 have the same distributions of bodily dimensions as would young men of ages 20, 21 and 22. Behind this are the questions of defining adulthood, of the ages at which bone growth ceases, and of extending the age range beyond that previously studied.

The population of young men studied "consisted of 17,341 Army men, distributed over the entire United States in a close approximation to the manner shown in the U.S. Census Report for 1940. In this series there were approximately 3000 each of ages 17, 18, and 19; 1500 of ages 20 and 21; and 1000 of ages 22, 23, 24, 25, and 26. Owing to the wide distribution over the United States, and to the medical acceptability of the men involved, insofar as the Army was concerned, the series may be considered representative of the healthy American male white adult to a great extent. The men in ages 17 and 18 were just being inducted into the Army, and were without previous military experience; those between 19 and 26 were being separated from the Army, and had received from 12 to 24 months military service. Consequently, we should keep in mind that some differences might occur between 18 and 19 which were a result of the military environment. In all cases, the age given is that of the last birthday of the individual, thus, age 25 includes men between 25 and 25 years and 364 days.

"The dimensions considered are as follows: Stature, Weight, Head circumference, Neck circumference, Sleeve length, Chest circumference, Waist circumference, Inseam, Stature-inseam, Hand length, Hand breadth, Foot length, and Ball foot circumference.

TABLE 71 - 1

Correlations Between Relative Measurements and Athletic Performance

	SPRINTERS (N = 46)					LONG-DISTANCE RUNNERS (N = 48)				
	Mean	σ	r	t	Significance	Mean	σ	r	t	Significance
Stature	177.4	5.93	+.31	2.162	+	172.2	6.17	+.04	.271	—
Relative lower limb length	53.4	1.19	+.02	.133	—	53.7	1.38	+.11	.751	—
Relative upper limb length	44.1	1.38	+.09	.597	—	44.8	1.57	+.28	1.979	+
Relative trunk length	30.4	1.22	+.05	.332	—	30.4	1.46	—.12	.820	—
Relative shoulder breadth	21.6	1.16	+.03	.199	—	21.9	1.14	—.22	1.530	—
Relative hip width	16.5	.84	+.01	.066	—	16.7	.87	—.12	.820	—
Relative chest circumference	51.9	2.49	—.42	3.070	++	52.5	2.10	+.15	1.029	—
Relative thigh circumference	30.0	1.73	—.30	2.086	+	29.2	1.30	+.18	1.241	—
Relative upper arm circumference										
Points (Ohls, '34)	885	74.33				986	85.96			

	JUMPERS (N = 33)					THROWERS (N = 45)				
	Mean	σ	r	t	Significance	Mean	σ	r	t	Significance
Stature	178.3	5.25	+.24	1.376	—	180.8	5.52	+.39	2.777	++
Relative lower limb length	53.4	1.21	+.15	.845	—	53.3	1.33	+.01	.066	—
Relative upper limb length	43.9	1.54	+.21	1.196	—	44.1	1.59	+.34	2.370	+
Relative trunk length	30.5	1.10	—.01	.056	—	30.7	1.40	+.04	.262	—
Relative shoulder breadth	22.0	.97	—.23	1.316	—	22.5	1.10	—.50	3.786	++
Relative hip width	16.2	.84	—.22	1.256	—	17.2	.81	—.01	.066	—
Relative chest circumference	51.7	2.38	—.32	1.881	—	55.0	2.71	+.37	2.612	+
Relative thigh circumference	30.3	1.34	—.11	.616	—	32.3	1.63	+.09	.590	—
Relative upper arm circumference						17.3	1.26	+.24	1.621	—
Points (Ohls, '34)	885	93.26				917	120.49			

"A brief definition of the methods of measurement of those dimensions not of use in usual anthropometry is in order. Sleeve length is obtained by placing the upper arm of the subject in a horizontal position, at an angle slightly forward of the transverse axis of the trunk, and the forearm at a 30-45 degree angle to the upper arm. The measurement, taken by tape, extends from cervicale to stylion with the tape passing over the olecranon process. Waist circumference is taken by tape horizontal to the floor at a level halfway between the lower costal margin and the iliac crests. Neck circumference is obtained with the tape just below the thyroid cartilage. Inseam, taken by anthropometer, extends from the nude crotch to the floor. Ball foot circumference is taken, by tape, over the heads of the metatarsals. Mean values of these dimensions for each of the age groups are listed in Table 72 - 1.

A brief comparison with growth studies already in the literature is used to establish a point of reference. The stature and weight curves of the Brush Foundation (Simmons, K. The Brush Foundation Study of Child Growth and Development. II. Physical Growth and Development.) are integrated with current material in Figures 72 - 1 and 72 - 2.

It is concluded that, "It should be clear that we are dealing with a range of years over which some portions of the body have ceased growth, while others are still involved in increase in dimension, even though we may not fully agree on terming this increase growth." The author discusses the problems of terminology, definition and of the need "to exert extreme care in the weighting of populations for comparative purposes."

The article includes one table, eight figures and a bibliography of four items.

TABLE 72 - 1

Mean Values of Certain Dimensions, for Ages 17-26, American Males, White, Military

	INDUCTEES		SEPARATEES							
	17	18	19	20	21	22	23	24	25	26
Weight	139.26	144.11	151.16	151.91	153.30	155.17	156.05	157.16	157.33	157.87
Stature	172.42	173.81	173.81	173.48	173.86	174.35	175.06	174.50	174.19	174.29
Head circumference	56.03	56.31	56.62	56.62	56.67	56.74	56.74	56.85	56.82	56.85
Neck circumference	35.23	35.69	36.42	36.50	36.63	36.83	36.88	36.98	36.93	37.03
Sleeve length	80.64	81.28	81.15	80.87	81.28	81.66	81.38	81.36	81.28	81.86
Chest circumference	87.63	89.31	90.86	91.14	91.77	92.38	92.74	93.09	93.34	93.37
Waist circumference	73.18	74.60	75.64	75.95	76.78	77.44	77.95	78.54	78.74	79.20
Inseam	84.20	84.73	83.77	83.54	83.49	83.79	83.52	83.74	83.49	83.49
Stature – inseam	88.37	89.23	90.20	90.07	90.50	90.73	90.70	90.88	90.83	90.91
Hand length	19.20	19.28	19.23	19.23	19.33	19.41	19.35	19.41	19.33	19.35
Hand breadth	8.61	8.66	8.61	8.69	8.76	8.81	8.79	8.79	8.79	8.79
Foot length	26.42	26.54	26.54	26.49	26.52	26.59	26.57	26.59	26.54	26.57
Ball circumference	24.61	24.66	24.59	24.59	24.74	24.79	24.71	24.74	24.69	24.71
Number	3166	3190	3016	1500	1369	1191	1023	902	981	1003

All dimensions are in centimeters, except for weight, which is in pounds.

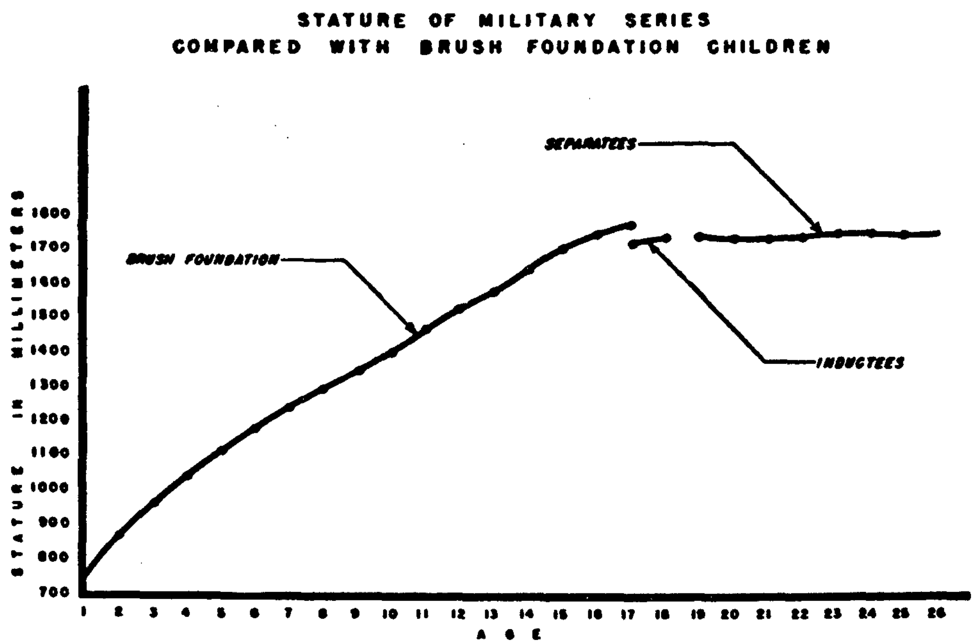


FIGURE 72 - 1

Stature of Military Series Compared with Brush Foundation Children

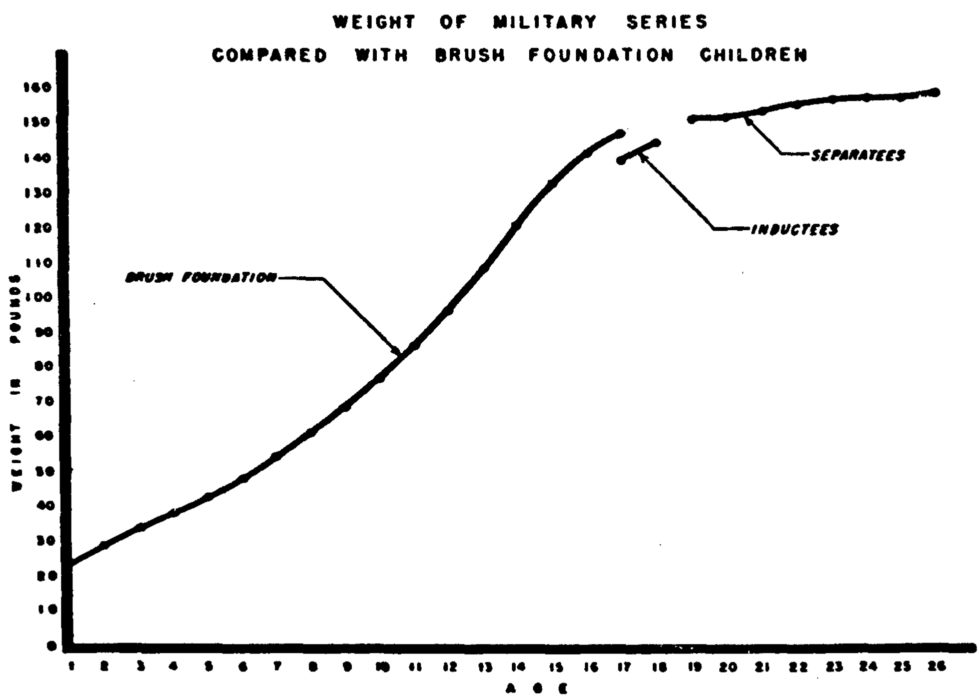


FIGURE 72 - 2

Weight of Military Series Compared with Brush Foundation Children

73. Randall, Francis E. Anthropometric Nomograph of Army White Men. Human Biology, Volume 21, No. 4, December 1949, pp. 218-232.

The subject matter of this reference appears in two different publications: the journal Human Biology, as above, and in the report An Anthropometric Nomograph of Army Men by F.E. Randall, Report No. 147, Quartermaster Research and Development Center, Natick, Massachusetts, January 1949. The article in the journal is likely to be more readily available.

The author notes that "the nomograph, then, provides a pictogram of a complex of variables, which may be subjectively studied to indicate generally the interrelationships present. Objectively studied, either as nomograph or as a series of equations, likenesses or differences within and between populations may be determined." A series of 24,500 male, white, Army separatees were the source of the twenty-five measurements, plus two dimensions collected on a smaller sample, for this analysis. Complete population data are presented in reference (Newman, R. W. and White, R. M. Reference Anthropometry of Army Men). The dimensions and the methods by which they were obtained are explained.

The preparation of the nomograph is described. "The first step is the selection of the two independent variables..; the second step is the preparation of a series of distributions of dimensions for each of several incremental categories of stature and chest circumference (stature and chest circumference were selected as the two independent variables)..; the third step is the calculation of regression equations showing the regression of a variable on stature and chest circumference..; (also) the calculation of the standard error of estimate of the regression..; finally, having determined the regression slopes and shapes, the basic data can be used to locate the lines of relationship on the nomograph."

The author notes that "with a nomograph at hand, several facts may be directly assessed. (1) The proportionate degree of correlation of a dependent variable to each of the independent variables. Those dimensions which lie closer to stature than to chest circumference are more highly related to stature than to girth... (2) A vertical line for the dimension indicates linear regression on both independent dimensions. (3) Dimensions between stature and chest are positively related to both. (4) Those dimensions to the left of stature decrease with increase in chest girth, and those to the right of chest circumference decrease with increase in stature. (5) A dimension sloping up and to the right, but straight, is linear in its regression on stature, but curvilinear in its regression on chest. A slope to the left, progressing upwards, would be the reverse. (6) A curved line indicates curvilinear regression on both independent variables."

The nomograph is included in this annotation. The article consists of fourteen pages and includes the nomograph, two tables and three literature references.

See also: Munro, Ella H. Anthropometric Nomographs. Environmental Protection Section, Report No. 184, Research and Development Branch, (US) Quartermaster Corps, February 1952, 19 p.

74. Randall, Francis E. Applications of Anthropometry to the Determination of Size in Clothing. Environmental Protection Division, Report No. 133, Quartermaster Research and Development Command, Natick, Massachusetts, 30 June 1948.

"The design and the size-determination of clothing, an art deriving its success from many years of experience and tradition, is an intensely practical study. Anthropometry, the measurement of the human body in highly refined detail, is a pure science and has been, in great part, impractical.

"The demand for mass-procurement of military clothing has necessitated the development of a system which embodies the fruits of research in both fields, in order to obtain and retain a better and more rigid standard in clothing sizes.

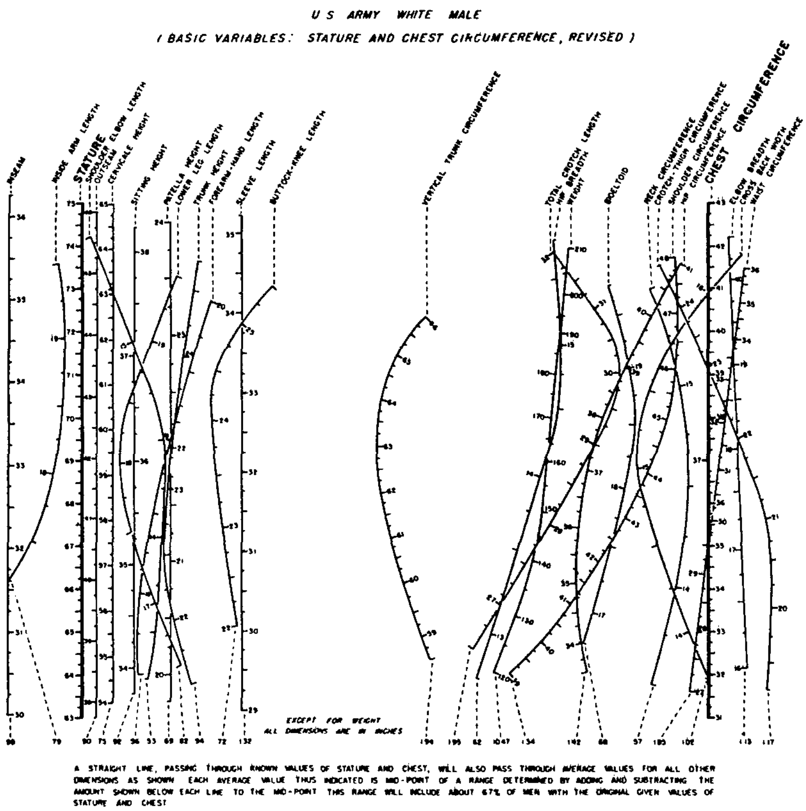


FIGURE 73 - 1

Anthropometric Nomograph of Army Men

"Since the two studies have heretofore been disassociated, this report endeavors to acquaint the professional designer with the thought patterns and problems of the anthropometrist."

The report describes procedures for taking 80 different kinds of measurements of the male and female body. Photographs are included to illustrate how the measurement should be accomplished.

The author supplies a list of bodily reference points (each defined) to be used in the measurement.

One chapter describes methods for determing the bodily proportions of individuals, another deals with differences in bodily proportions between the male and female groups.

The author discusses the use of the experimental method in clothing design and describes the application of statistical and mathematical techniques to the problem.

The report is 108 pages long, including 34 numbered tables and 12 figures. Six bibliographical references are listed.

75. Randall, Francis E. and Ella H. Munro. Anthropometric Nomograph of Army Women. Environmental Protection Division, Report No. 148, Quartermaster Research and Development Center, Natick, Massachusetts, 10 February 1949.

A series of 8500 members of the Women's Army Corps and Army Nurse Corps was analyzed from the standpoint of its composition, in terms of age, military function, education, and regional distribution. The age range of the total series was from 18 to 54 years, with 73% falling in the 18-29 year range utilized for the present study.

Eight measurements were studied as they were related to Cervicale Height and Hip Circumference within the population. The interrelationships have been expressed in mathematical terms and, from the equations resulting, a nomograph has been prepared which describes these mathematical interrelationships. The nomograph is included in the present abstract.

"To be able to approximate the dimensional values of any single values of Cervicale Height and Hip Circumference, the nomograph, Figure 75 - 1, was prepared. The method of use is simple. By connecting the known values of Cervicale Height and Hip Circumference by a straight line, the mean value of each of the other dimensions will be indicated at the intersection of the straight line with the various other lines. By adding and subtracting the value shown at the bottom of each line to and from the indicated mean, the range for 70% of women with those desired Cervicale Height and Hip Circumference values may be approximated. Plus and minus twice this value will include 95% of the women, as described above."

"The nomograph may also be used in another way. If the designer should be interested in the range of Waist Circumference associated with women who range between 54 and 55 inches in Cervicale Height and between 37 and 38 inches in Hip Circumference, by connecting 54 with 37, 54 with 38, 55 with 37, and 55 with 38, a total spread of ranges will be determined, and then, by connecting the mid-points of the two ranges Waist Circumference may be read. By adding and subtracting the value which lies below the waist girth line, the 70% range is established. Addition and subtraction of twice this value will set up the 95% range."

"This nomograph represents reference to a specific population consisting of definite age groups and regional compositions and must not be used to describe a population which differs in any category from that which exists in the original series. Differences in age composition, regional origins, etc., will affect the values which would be determined and might materially compromise any decisions which may be made on the basis of this particular graph. Before using the nomograph for problems, it will be wise to compare the population associated with the problem with the group upon which the graph data are based, particularly with respect to age."

Measurement techniques are described and a short bibliography is included.

76. Randall, Francis E. and Ella H. Munro. Reference Anthropometry of Army Women. Environmental Protection Division, Report No. 149, Quartermaster Research and Development Center, Natick, Massachusetts, 31 March 1949.

One hundred and nine regression tables and ninety-eight bivariates are presented in this report to indicate a wide variety of interrelationships of pairs of body dimensions which exist on a sample of women's population in the Army. These data should serve as a guide to the designers of equipment for use by Army women.

Body size data for a series of measurements of approximately 8500 members of the Women's Army Corps and Army Nurse Corps were obtained in a 1946 Quartermaster survey. The age range of the subjects was from 18 to 54 years, with 88.72% falling in the 18-34 year range.

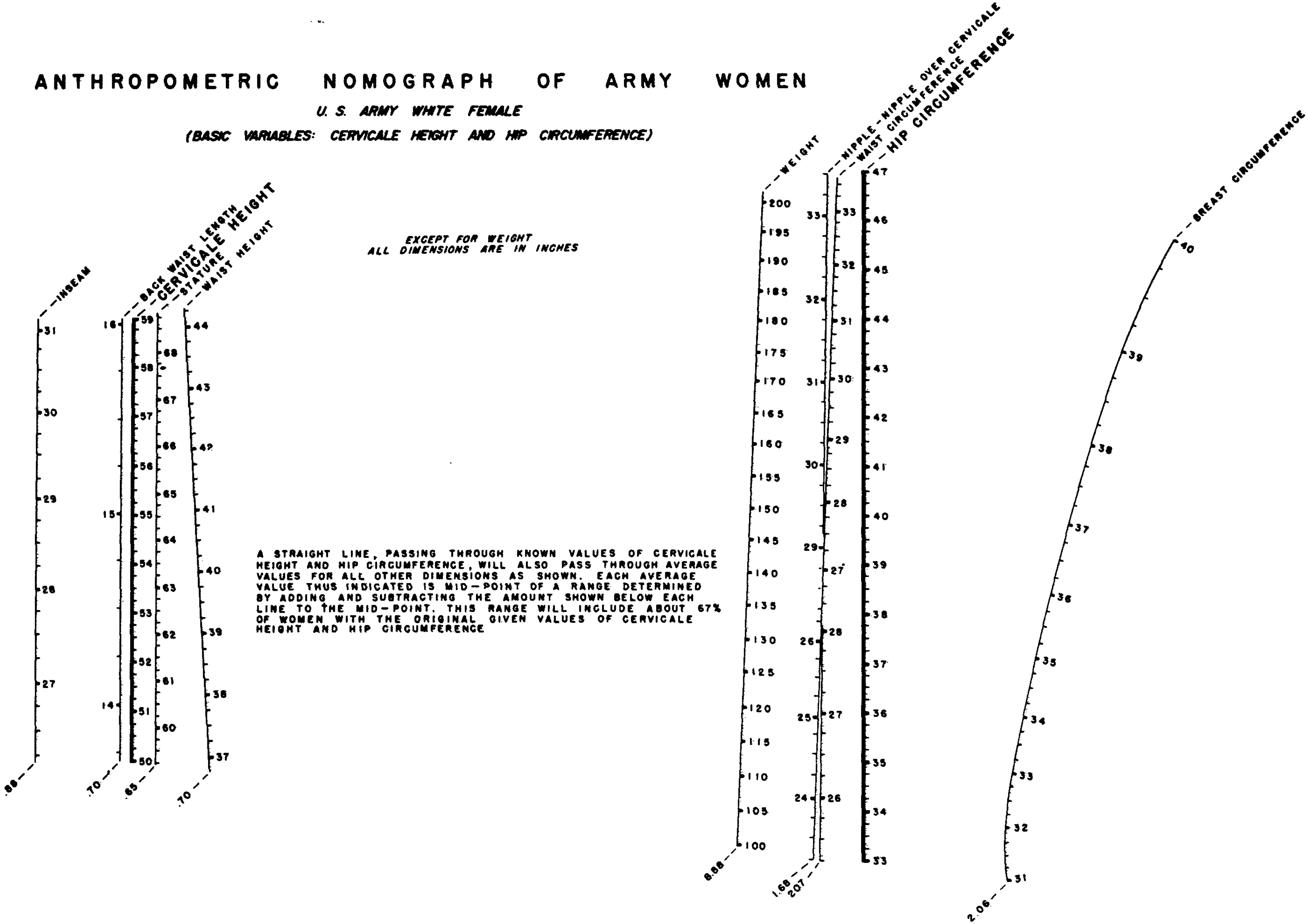


FIGURE 75 - 1

Anthropometric Nomograph of Army Women

"The women measured had been in the military service for varying lengths of time, and, consequently, represent a sample of women who not only were involved in military selection, but further had been subjected to military environments. As such, these women should serve to provide a general description of a highly selected and conditioned group, and the data which...(are)...discussed in this report must be considered as being indicative only of women already selected and exposed to a rigid set of conditions. Women just entering the military service, as well as those outside it, may be quite different, not only in the distribution of their sizes, but perhaps in the actual composition of their bodily proportions."

The regression tables and bivariates include such data as the relationship of breast circumference to cervicale-lateral neck point, hip circumference, waist circumference, halfway to hip circumference, chest circumference, cross back width, shoulder length, back waist length, should-elbow, upper arm circumference, nipple-nipple over cervicale, trunk height, lateral neck point-waist, nipple-nipple, neck circumference, arm scye, wrist circumference, forearm circumference, chest breadth, cervicale height. A total of 51 dimensions are considered in varying detail.

A discussion of the statistics utilized is included in the report, whose 241 pages are primarily tables of data. No bibliographic references are included.

See also: Quartermaster Corps, U.S. Army. Survey of Body Size of Army Personnel, Male and Female (1946): Body Dimensions of Army Females. Project No. E-59-46, Environmental Protection Section, Quartermaster Research and Development Center, Natick, Massachusetts.

Randall, Francis E. Anthropometric Nomograph of Army Women. Environmental Protection Section. Report No. 148, Research and Development Branch, Quartermaster Corps, 10 February 1949.

Munro, Ella H. Anthropometric Nomographs. Environmental Protection Section Report No. 184, Research and Development Branch, (US) Quartermaster Corps, February 1952, 19 p.

Randall, Francis E. Survey of Body Size of Army Personnel, Male and Female. Project No. E-59-46. Phase 4 (Body Dimensions of Army Females.) Environmental Protection Section Report No. 123, Research and Development Branch, Quartermaster Corps.

77. Roberts, D.F. Body Weight, Race and Climate. American Journal of Physical Anthropology, New Series, Volume 11, No. 4, December 1953, pages 533-558.

"The geographical distribution of mean body weight in indigenous populations suggests an inverse relationship with mean environmental temperature. Statistical analysis showed this association to be highly significant, both before and after the influences of stature and group affinity were taken into account. There are differences in weight among geographical groups or varieties of man, not attributable to the temperature and stature relationships.

"The ecological significance of the results is discussed, and some genetic influence suggested."

The article is 25 pages long and includes six tables and eight figures. A bibliography of 20 references is listed. A three page tabular appendix included in the article is reproduced herewith.

APPENDIX 77 - 1

Samples used in the Statistical Examination

GROUP	NO. IN SAMPLE	WEIGHT	STATURE
		kg	*cm*
African			
Kikuyu	436	51.9	164.6
Masai	76	61.3	172.0
Sandawe	100	49.4	164.6
Nyaturu	50	52.2	165.4
Pygmy	111	40.1	142.2
Pygmy	36	39.3	142.2
Bushman	34	40.4	156.4
Bushman	54	40.4	155.4
Kikuyu	100	51.8	164.0
Gagou	24	42.6	159.3
Efe	386	39.8	143.8
Akka	115	40.0	144.4
Djem	100	56.6	162.9
Dzimou	83	57.7	163.4
Yambasa	248	62.0	169.0
Badjoue	200	55.0	166.6
Baya	412	53.9	163.0
Kirdi	332	56.2	165.8
Kirdi	549	58.0	167.0
Batutsi	177	57.4	176.5
Batutsi	119	56.3	175.2
Bakiga	70	64.5	168.4
Bahutu	184	57.5	167.1
Bahutu	216	56.7	165.9
Imbo	28	49.5	161.3
Batwa	113	48.7	155.3
Bashi	108	53.5	163.9
Warega	100	57.2	162.1
Australian			
Central tribes	20	53.1	169.7
Central tribes	27	56.9	168.7
Melanesian			
Jabim	26	56.4	161.0
Aua	29	54.3	157.1
Massawa	49	58.7	160.5
Mira	20	53.1	161.5
American			
Eskimo	30	65.3	162.7
Maya Quiche	30	57.6	159.3
Mapuche	31	66.8	163.3
Maya	24	52.4	158.0
Maya	30	54.4	156.0

APPENDIX A *(continued)*			
GROUP	NO. IN SAMPLE	WEIGHT	STATURE
		kg	*cm*
Maya	32	53.1	157.3
Choctaw	33	67.8	171.4
Yaqui	100	64.0	166.7
Zuni	348	56.3	161.4
Hopi	276	60.8	161.1
Navaho	125	62.7	169.6
Peru	many	55.5	159.0
Peru	many	56.8	159.0
Maya	70	53.7	156.4
Eskimo	121	62.1	159.3
Eskimo	39	63.5	165.7
European			
Greek	80	64.4	164.8
Sicily	29	59.2	162.4
England	3000	64.5	166.3
Iceland	652	68.1	173.6
London	46	70.1	179.4
Kainuu	many	69.8	170.4
Pohjanmaa	many	71.0	171.9
Häma	many	71.0	171.7
Savo	many	68.0	169.6
Karjala	many	68.6	169.7
Varsinais	many	71.3	172.5
Uusimaa	many	70.3	171.4
London	many	62.2	172.2
Edinburgh	many	61.8	170.4
Glasgow	many	60.5	169.4
Southeast England	many	63.0	173.0
Cornwall	many	63.0	171.7
Staffordshire	many	60.8	170.9
Paris	2619	67.0	172.5
Bulgars	121	67.1	167.2
Central Asian			
Kirghiz	40	59.7	165.3
Kazak	30	69.7	163.1
East Mongoloid			
Javanese	24	48.9	163.6
Javanese	33	52.9	164.3
Malay	50	55.5	166.4
Banjerese	35	51.3	157.0
Sundanese	37	54.4	159.1
Sundanese	200	51.4	159.9
Mentawei	202	51.5	156.5
Filipino	88	53.0	163.0

APPENDIX A *(continued)*

GROUP	NO. IN SAMPLE	WEIGHT	STATURE
		kg	*cm*
Pekin	49	59.2	169.3
Pekin	34	53.6	167.2
Hongkong	87	52.7	166.0
Szechwan	54	51.7	165.0
Miao	24	46.4	154.0
Japanese	42	51.9	161.9
North China		61.0	168.0
Central China	351	54.0	165.0
South China		54.0	165.0
South China	30	52.3	163.4
North China	23	50.9	159.0
Central China	328	54.7	163.0
Hongkong	115	51.8	166.3
Korea (Chung Chong)	27	55.8	161.3
Korea (Kyong Kwi)	354	55.5	161.1
Korea (Hwanhai)	22	55.6	160.3
Korea (Pjonjan)	45	56.8	163.0
Korea	594	59.2	163.2
Hoklo	117	53.6	162.7
Orochee	93	59.5	155.0
Naga	33	51.5	160.3
Polynesian			
Maori	384	74.5	170.6
Hawaii	60	77.3	171.3
South Asian			
Santal	313	45.0	159.3
Malpaharia	60	41.6	156.3
Sauriapaharia	69	41.4	156.2
Mande	23	53.6	158.8
Senoi	39	48.1	156.4
Senoi	39	47.0	154.6
Indian			
Bengal	1193	52.7	165.8
Brahmin	100	55.5	163.8
Mahratta	162	55.7	163.8
Bombay	60	55.5	167.9
Hyderabad	32	54.2	169.3
Bombay	24	52.5	166.0
Madras	61	53.1	167.0

78. Roberts, Lester B. and others. Size Increase of Men Wearing Various Clothing Combinations. Project No. 9, SPMEA 741-3 (Partial Report), Armored Medical Research Laboratory, Fort Knox, Kentucky, 20 October 1945.

"The Armored Medical Research Laboratory was requested by Ordnance to furnish data on increase in size resulting from various clothing combinations, the data to be used by tank and vehicle designers in arriving at spacial requirements for vehicle crewmen." Measurements to be used in estimating increments were obtained by micrometer on one set of G.I. clothing unless specified to the contrary (N = 1).

"Many of the measurements are subject to wide variability depending on snugness or looseness of fit, hang of cloth, etc. Table 78 - 1 gives minimum increase tabulation for certain clothing combinations. ...Table 78 - 2 is a reproduction of Army Air Force data on amounts added to nude dimensions by typical clothing outfits..." (Damon, A. Effect of Flying Clothing on Body Measurements of Army Air Force Flyers.)

The report is 12 pages long, including two tables and nine figures. There is one bibliographic reference.

79. Sandberg, K.O. William and Harold L. Lipshultz (New York University). Maximum Limits of Working Areas on Vertical Surfaces. Report No. 166-I-8, Office of Naval Research, U.S. Navy, Reprint April 1952 (ASTIA No. ATI-205845).

"This experiment measured the maximum area which can be reached on a flat vertical surface by the two arms of eight male subjects seated at varying viewing distances away from the surface. The paper discusses the influence of some of the variables: viewing distance, arm length, and body distance between pivot centers.

"It was found that each arm described an approximate circle whose diameter decreased as the distance between the subject and the flat vertical surface was increased. The three viewing distances of 10 inches, 15 inches, and 20 inches were selected as representative of actual operating practice." "Other studies (Randall, F.E., Damon, A., Benton, R.S., and Pratt, D.I. Human Body Size in Military Aircraft and Personal Equipment. USAF, Air Materiel Command) have measured variations in body sizes. Stature varies by more than 12 inches, weight by more than a hundred pounds, anterior arm reach*by more than ten inches. Typical male anterior arm reach may range from 29.5 inches to 40.6 inches. The bideltoid distance**varies by five inches. Sitting height varies almost eight inches."

*"Heels together; heels, buttocks, middle of back (in lateral sense), and occiput against wall. Subject is required to attain maximum horizontal forward reach, with contacts maintained. Both arms horizontal, extended equally. Distance from wall to tip of middle finger."

**"Arms at side, palms forward. Maximum contact dimension across deltoids (large muscles around shoulders)."

"At the distance of 20 inches from eye to vertical panel, the average subject described a circle of 40.4 inches diameter with each arm. The two circle centers were approximately 12 inches apart, horizontally. When adjusted for the average anterior arm reach for almost 3000 AAF cadets, the circular diameter is 43.5 inches. The area enclosed by two such 43.5-inch circles is the maximum area of reach for operators of approximately average size.

"At the same distance of 20 inches from eye to panel, a very small subject (short arms and of slight build) can describe two smaller overlapping circles of 34.8 inches diameter with centers separated horizontally by approximately 9.1 inches. These circles enclose the whole area of Figure 79 - 1 which takes the rough shape of an ellipse whose axes are 43.9 inches and 34.8 inches. It is estimated that 95% of all possible operators will be able to reach all points in this field.

"When a manual task requires both hands to be at the same place simultaneously, the points which can be reached without a posture change are then limited to the common area of the two overlapping circles. These common points are shown for a subject of small size at 20 inches viewing distance by the inner hatched area of Figure 79 - 1. This area approximates an ellipse whose major and minor axes are 33.6 inches and 25.8 inches respectively. However, it was found that a slightly smaller common

TABLE 78 - 1

Minimum Increase Tabulation for Certain Clothing Combinations

AMOUNTS ADDED TO NUDE DIMENSIONS BY CLOTHING(1) (Inches)	Helmet, Liner, Khakis, Cotton Undershirt and Drawers, Socks and G.I. Shoes	Helmet, Liner, Field Jacket, Khakis, Cotton Underwear, Socks and G.I. Shoes	Helmet, Liner, Fatigues, Cotton Underwear, Shoes and Socks	Helmet, Liner, Gloves, Wool Cap, Fatigues, Combat Suit, Cot. Underwear, Shoes and Socks	Helmet, Liner, O.D's, Cotton Underwear, Shoes and Socks	Same with Blouse	Same with Blouse and Overcoat	Same with Field Jacket	Helmet, Liner, Cap, Cotton Underwear, Fatigues, Combat Suit, Gloves, Overcoat, Shoes and Socks
Weight (pounds)	9.1	10.0	9.4	15.9	9.3	11.8	18.6	9.8	22.9
Stature(2) (inches)	2.65	2.65	2.65	2.75	2.65	2.65	2.65	2.65	2.75
Head Length	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Breadth	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Height(3)	1.35	1.35	1.35	1.45	1.35	1.35	1.45	1.35	1.45
Arm - Total Span	-	-	-	.30	-	-	-	.30	.30
Span Akimbo	.04	.12	.04	.46	.04	.12	.36	.12	.70
Anterior Arm Reach	.04	.08	.04	.25	.04	.08	.20	.08	.37
Shoulder-Elbow Length (padding included)	.14	.28	.14	.34	.14	.50	.94	.28	.62
Shoulder Breadth (to bone) (seam or padding included)	.24	.44	.24	.52	.24	.88	1.52	.44	1.16
Shoulder Breadth (across muscle)	.04	.12	.04	.16	.04	.12	.36	.12	.40
Elbow Breadth (across body)	.56	1.04	.56	1.24	.56	1.04	1.84	1.04	2.12
Hand Length	-	-	-	.15	-	-	.15	-	.15
Hand Breadth	-	-	-	.30	-	-	-	-	.30
Trunk Sitting Height	1.39	1.43	1.39	1.55	1.39	1.39	1.61	1.39	1.67
Eye Level from Seat	.04	.08	.04	.10	.04	.04	.16	.04	.22
Shoulder to Seat	.16	.30	.16	.36	.16	.48	.92	.58	.80
Chest Depth	.21	.96	.41	0.79	.21	.85	1.80	.85	1.54
Abdominal Depth	.94	1.18	.94	1.79	.94	1.18	1.95	1.18	2.54
Hip Breadth	.52	.72	.52	1.08	.56	.76	1.08	.76	1.40
Buttock Breadth	.52	.52	.52	1.08	.56	.76	1.08	.56	1.40
Buttock-Knee Leg (sitting)	.20	.20	.20	.46	.20	.30	.54	.30	.70
Knee Height(2) from Floor	1.32	1.32	1.32	1.32	1.32	1.32	1.44	1.32	1.44
Knees Breadth across Both	.48	.48	.48	1.04	.48	.48	.72	.48	1.68
Foot Length(4)	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60
Foot Breadth(4)	.20	.20	.20	.20	.20	.20	.20	.20	.20

(1) These data were calculated from maximum thickness measurements with a micrometer on one set of G.I. Clothing; unless otherwise noted.

(2) Shoe Height is a mean of 32 Height measurements on men with and without shoes.

(3) Head Height gains are from measurements on one man with and without head protection.

(4) From foot and shoe measurements on one man.

TABLE 78 - 2

Amounts Added to Nude Dimensions by Typical Clothing Outfits

	Heavy Winter Flying Clothing[1]	Quilted "Feathertex" (Thomas Quilt)[2]	Electrically Heated Suit (Type F-1)[3]	Electric Suit (G.E. 2-piece)[4]
Weight	20 lbs.	14 lbs.	16 lbs.	15.5 lbs.
Stature	1.9 in.	1.9 in.	1.8 in.	1.2 in.
Head Length	0.4	0.4	0.4	0.4
Breadth	0.4	0.4	0.4	0.4
Height	0.2	0.2	0.2	0.2
Circumference	1.7	1.7	1.7	1.7
Arm				
Total Span	0.4	0.0	0.2	0.0
Span-Akimbo	0.8	0.0	0.4	0.0
Anterior Arm Reach	0.4	0.0	0.2	0.0
Shoulder-Elbow Length	0.3	0.3	0.5	0.5
Shoulder Breadth (to bone)	1.3	0.8	0.4	0.2
Shoulder Breadth (across muscle)	0.7	0.8	0.5	0.2
Elbow Breadth (across body)	4.4	4.7	2.4	2.9
Hand Length	0.3	0.4	0.4	0.2
Hand Breadth	0.4	0.3	0.2	0.2
Trunk				
Sitting Height	0.6	0.6	0.6	0.6
Eye Level from Seat	0.4	0.4	0.4	0.4
Shoulder to Seat	0.6	0.7	0.5	0.5
Chest Breadth	0.6	0.6	0.4	0.5
Chest Depth	1.4	1.7	0.7	0.7
Chest Circumference-resting	9.1	6.8	4.4	3.4
Abdominal Depth	1.4	2.2	0.4	0.8
Hip Breadth	1.3	2.1	0.4	0.8
Buttock Breadth	1.7	2.5	0.5	0.6
Leg				
Buttock-Knee (sitting)	0.5	1.1	0.4	0.3
Knee Height from Floor	1.8	2.2	1.6	1.9
Knees, Breadth across Both	2.5	2.1	2.5	1.0
Calf Circumference	6.0	3.9	1.6	1.8
Foot Length **	2.7	2.7	2.7	2.7
Foot Breadth **	1.2	0.9	0.7	0.9

[1]B-3 jacket, A-3 trousers, B-5 helmet, A-9 gloves, A-6 boots.
[2]SJ-4* jacket, ST-9* trousers, B-6 helmet, A-9 gloves, A-6 boots.
[3]F-1 suit, B-5 helmet, A-6 gloves, A-9 boots, D-1 boot pilots.
[4]PA-17-LI* jacket, PA-17-MI* trousers, B-6 helmet, PA-17-DI* gloves, A-6 boot, A-4 coverall.

* Manufacturer's numbers: Thomas Quilt Factories, Denver, Colorado; General Electric Company, Bridgeport, Connecticut.
**Boot Measurements: A-6, medium: 12.8" long, 5.0" wide. A-6, large: 13.5" long, 5.3" wide. A-9, large: 13.2" long, 4.7" wide.

area of two overlapping circles is described by a subject of short arms but broad build at 20 inches viewing distance. Figure 79 - 2 shows this ellipse as a double cross-hatched area with axes of 32.0 and 21.1 inches. Other values under different conditions are given in several tables in the report."

The nineteen pages of this report include six figures, seven tables and one bibliographic reference. Two figures are presented with the annotation.

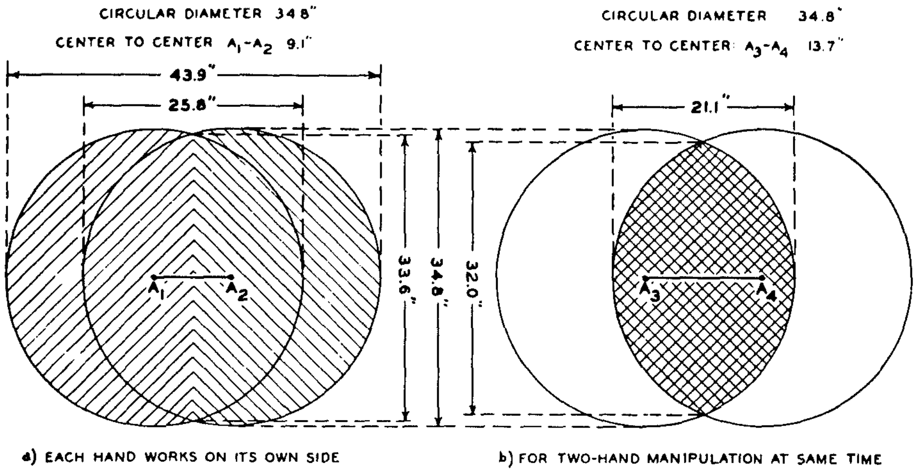


FIGURE 79 - 1

The Conservative Limits of Maximum Working Areas

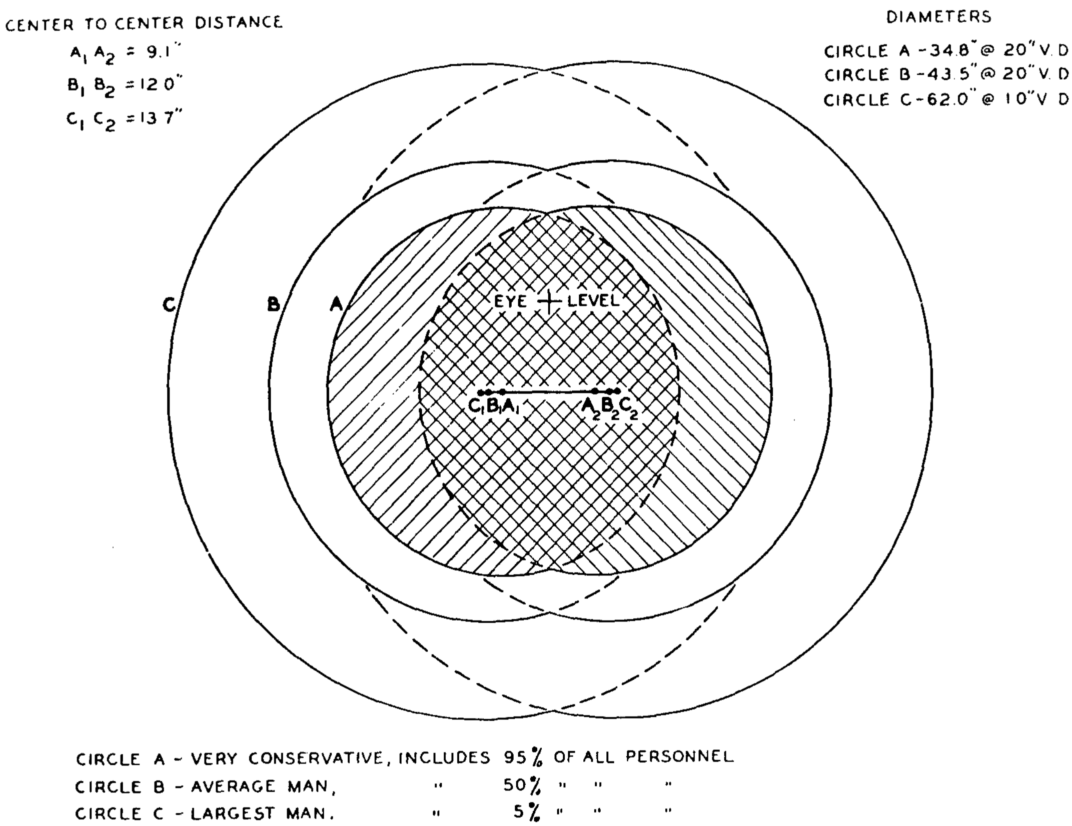


FIGURE 79 - 2

The Limits of Maximum Working Areas

80. Saul, Ezra V. and Jack Jaffe. Effects of Clothing on Gross Motor Performance. Technical Report EP-12, Quartermaster Research and Development Center, Natick, Massachusetts, June 1955.

"An investigation was carried out to determine the usefulness of 28 performance tests and devices which might reliably reflect the restriction effects of Quartermaster clothing and personal equipment. In general, these were tests of flexibility, steadiness and coordination of gross motor movement. The data obtained were analyzed with respect to reliability, sensitivity and interrelations of the tests with each other. A majority of the tests indicated that performance is impaired as amount of clothing is increased. Certain of these tests showed considerable promise as useful methods for evaluating clothing restriction.

"The design of the present study required a group of fifteen subjects to perform a number of motor tasks while wearing each of three clothing ensembles. Each subject served as his own control by being tested under all clothing conditions and on all motor tasks.

"The clothing ensembles utilized in the present experiment and the experimental conditions associated with them... .

Baseline Condition (B): "T" shirt, athletic supporter, track shorts, athletic socks, and wrestling sneakers.

Experimental Condition I (E-1): Underwear, winter, pajama type; shirt, field, wool; trousers, field, wool; suspenders, trousers; socks, wool, cushion sole; boots, combat, rubber, insulated.

Experimental Condition II (E-2): All of the clothes used in Experimental Condition I plus: jacket, shell, field; liner, jacket, field; trousers, shell, arctic. (All items in experimental conditions I and II were regular Army issue.)

"These clothing outfits were selected as being representative points along a continuum of minimal to maximal clothing, and typical of a range of clothing an individual might wear and still be capable of some degree of efficiency in motor performance. Military clothing items were used to enhance the relevance and applicability of the study's findings to problems within the military establishment. Subjects were fitted with clothing by a physical anthropologist familiar with problems of military clothing.

"The subjects were fifteen Tufts College students selected by criteria of age, weight, height and physical fitness. These men ranged from 17 1/2 to 24 1/2 years of age with a median age of 20 years. Their weights varied from 140 to 165 pounds with a median weight of 153 pounds. The heights of this group ranged from 66 1/2 to 72 inches, with a median height of 68 1/2 inches. Nine of the subjects were members of the College's ROTC units at the time of the experiments; all of them were engaged in varsity or intramural athletics.

"Since these selection criteria were comparable to those for selection of the present military population, the results of the present study are considered generally applicable to appropriate problems within the Army.

"Experimental sessions were two hours in duration and were marked with frequent rest periods. Rest periods were used to minimize fatique and heat stress. Further, the tasks were so grouped and spaced over the seven-week experimental period that no given experimental session was markedly more demanding on the subject than any other. Tests 1 through 10 were administered during the first four weeks of testing, 11 through 25 during the fifth and sixth weeks, and 26 through 28 during the seventh and final week of the experiment. In the first ten tests, subjects were tested in only one clothing condition per session, whereas in the other tests, subjects were tested under all clothing conditions in a given session.

"The present findings generally reaffirm what is usually supposed to be the case; that is, that clothing can and does interfere with the efficiency of the wearer's motor activity. The study also shows that quantitative measures can be developed and applied to the evaluation of the effects of clothing on motor performance. This has several implications:

"Insofar as the present results are applicable to Army conditions and populations, some inefficiency in motor performance can be attributed to the wearing of presently designed military uniforms. Whether such detrimental effects of clothing are to be judged critical in military job situations and eliminated is dependent on future research and the application of other than the presently utilized criteria of statistical significance."

The tests studied were: (1) Stabilometer, (2) Five Steps for Distance - Backward, (3) Five Steps for Distance - Left Sidestep, (4) Railwalking, (5) Sitting Flexion, (6) Five Steps for Distance - Forward, (7) Standing Trunk Flexion, (8) Static Steadiness - Longitudinal Foot Position, (9) Static Steadiness - Transverse Foot Position, (10) Five Steps for Distance - Right Sidestep, (11) Trunk Extension, (12) Truni Flexion, (13) Shoulder Extension, (14) Head Flexion, Ventral, (15) Head Flexion, Dorsal, (16) Head Flexion, Lateral, (17) Head Rotation, (18) Upper Arm, Forward Extension, (19) Upper Arm, Backward Extension, (20) Upper Arm Abduction, (21) Forearm Flexion, (22) Lower Leg Flexion, (23) Upper Leg Flexion, (24) Upper Leg. Backward Extension, (25) Upper Leg Abduction.

The 33 pages of this report include 31 figures, 5 tables, and 23 bibliographic references.

81. Sendroy, Julius, Jr., and Louis P. Cecchini. The Determination of Human Body Surface Area from Height and Weight. Research Report: Project NM 004 006.05.01, Naval Medical Research Institute, National Naval Medical Center, Bethesda, Maryland, 19 October 1954 (ASTIA No. AD-44829). (Published, in part, in Journal of Applied Physiology, Vol. 7, No. 1, July 1954, pp. 1-12.)

"A simple, rapid, and accurate method of calculating human body surface area from height and weight has been developed. From the empirical relationships of height plus weight (in cm and kg, respectively), and the "shape" factor of the ratio of weight to height, charts have been constructed for the graphical estimation of surface area values in the range from 0.05 to 3.0 m^2. From these master charts a diagram has been constructed whereby surface areas may be obtained with the same accuracy and more conveniently, from values of height and weight alone. To facilitate its use in respect to convenience and accuracy this working diagram is included in this report in a suitably enlarged form.

"A comparative evaluation and statistical analysis of the method applied to 252 measurements of surface area has been made. The complete data for the measured and calculated surface area values upon which this work is based are included as an appendix to this report. The results indicate a margin of superiority in respect to accuracy, especially in the case of abnormal body types, for the present graphical method as compared with the well-known Du Bois height-weight formula. The self-adjusting power equation of Boyd has been found to give results generally comparable to those obtained by our diagram. According to these tests, the equation of Breitmann has been found to be biased and not sufficiently accurate to merit consideration for further use. All factors considered, the presently proposed graphical method would seem to be generally superior to other methods of obtaining a value for surface area from the simple physical measurements of height and weight. A consideration of the rationale of the anthropometric relationships evolved, indicates that they are in accord with accepted concepts pertaining to the growth and development of the human body."

The 24 pages of this report include 3 tables, 4 figures and a bibliography of 32 references. Three of the figures are included in the annotation.

Additional references: DuBois, E.F. and D. DuBois. Formula to Estimate Approximate Surface Area if Height and Weight be Known. Archives of Internal Medicine, Vol. 17, 1916, p. 863.

Benedict, F.G. A Photographic Method for Measuring the Surface Area of the Human Body. American Journal of Physiology, Volume 41, 1916, pp. 275-291.

Rodahl, K. and J. Edwards Jr. Project Report No. 22-1301-0001, Part 1 (Eskimo Study-body Surface). Arctic Aeromedical Laboratory, Ladd Air Force Base, Alaska, May 1952.

Boyd, E. The Growth of the Surface Area of the Human Body. Minneapolis: University of Minnesota Press, 1953.

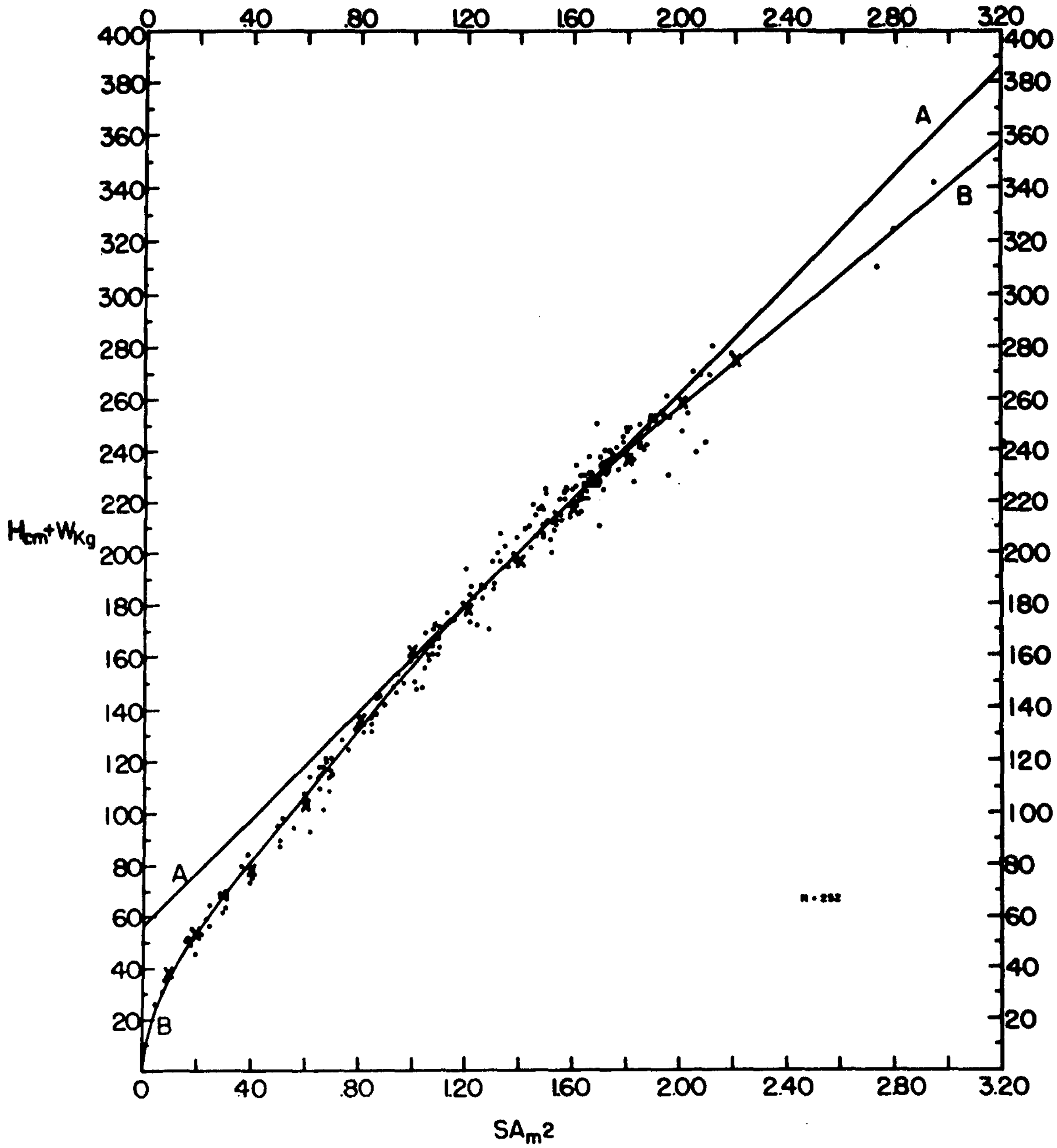


FIGURE 81 - 1

Relationship of the sum of height and weight to measured values of the surface area for 252 human subjects. Line A represents the cases in the range SAm^2 = 0.8 - 2.2. Line B represents the entire population studied.

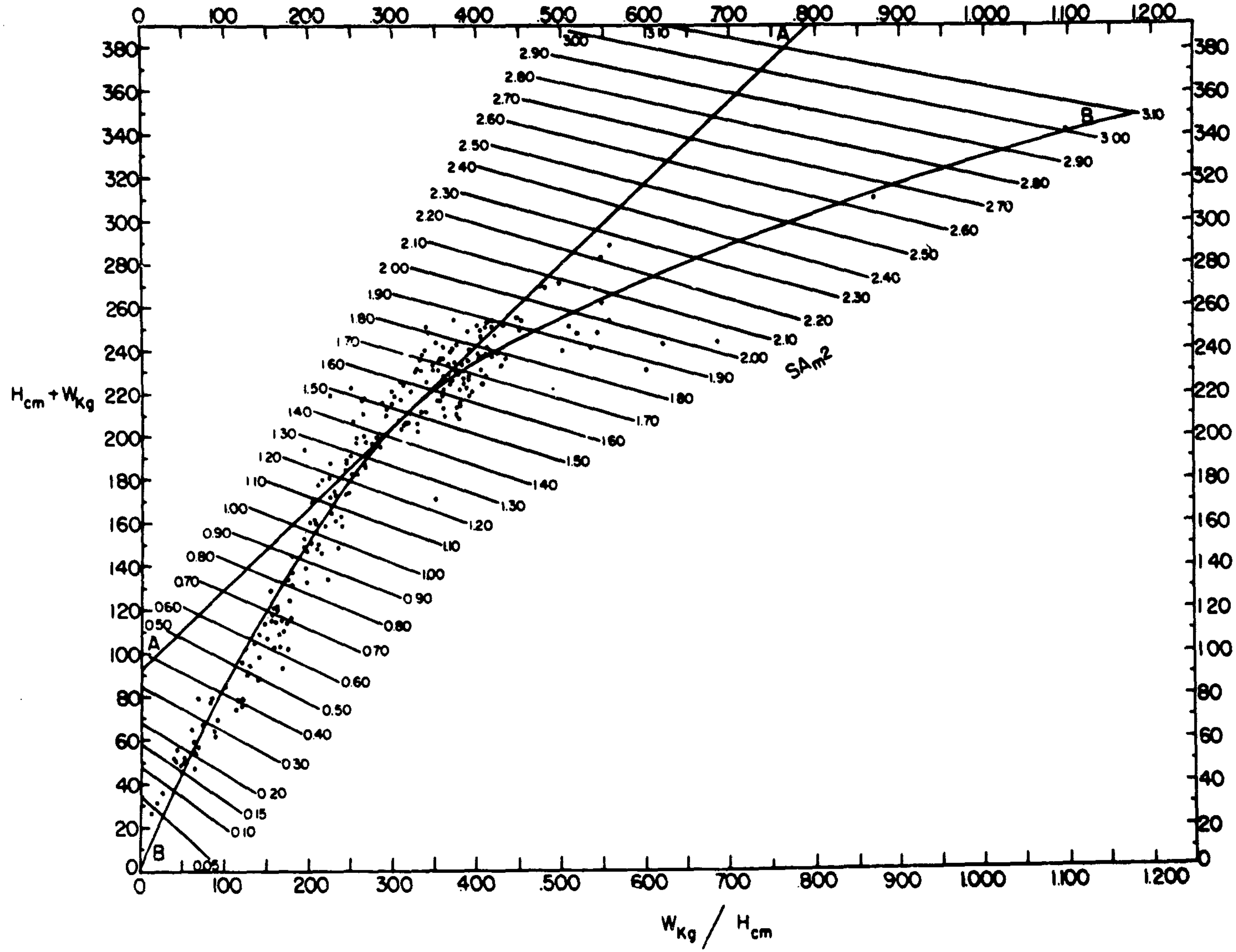


FIGURE 81 - 2

Diagram for the determination of human surface area from the height and weight relationships (H + W) and W/H. Lines A and B represent the corresponding populations designated in Figure 81 - 1.

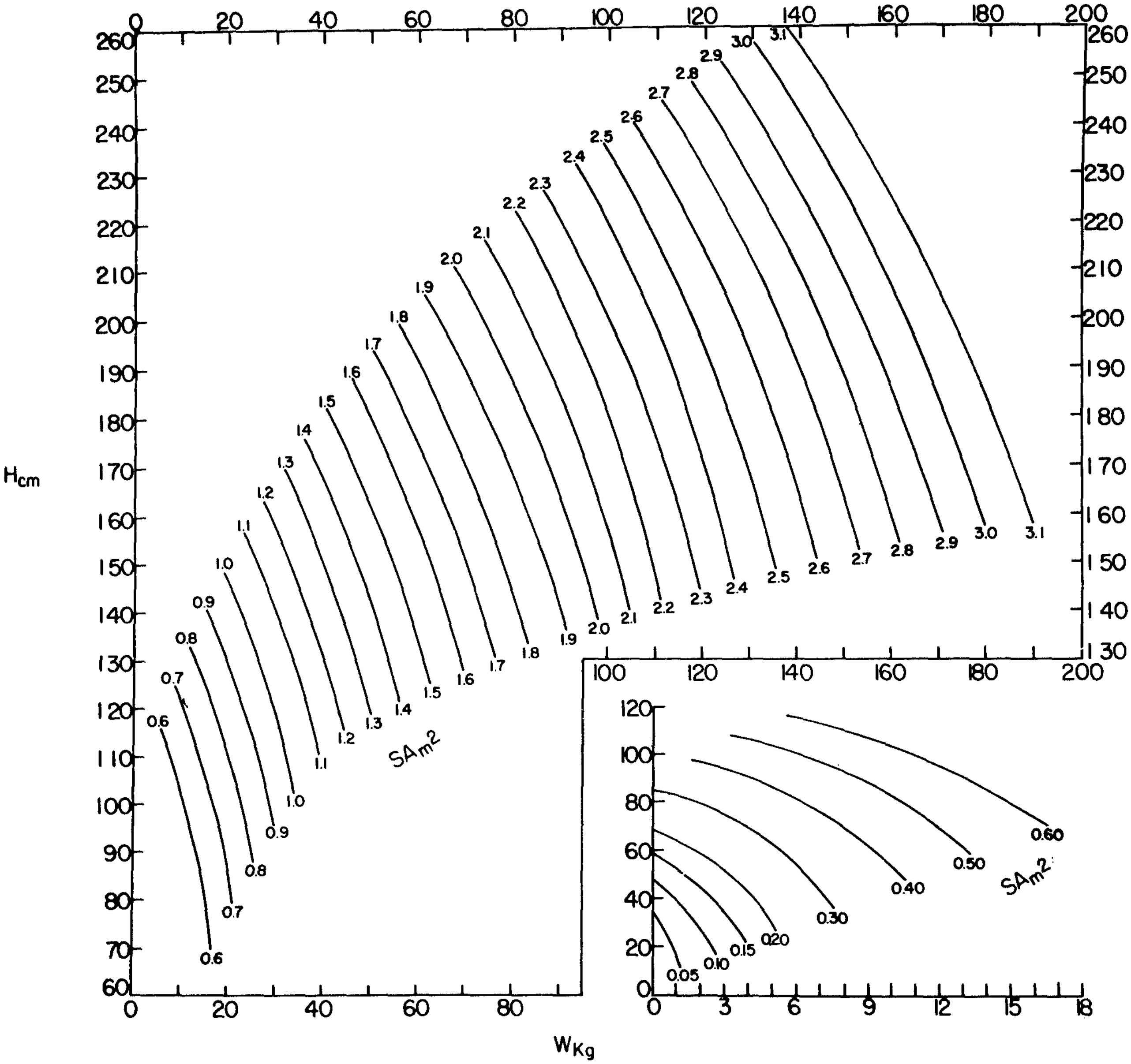


FIGURE 81 - 3

Diagram for the determination of human surface area from height and weight. Insert is used for low range of SAm^2 from 0.05 to 0.60.

82. Skerlj, Bozo, Joseph Brozek, and Edward E. Hunt, Jr. Subcutaneous Fat and Age Changes in Body Build and Body Form in Women. American Journal of Physical Anthropology, New Series, Volume II, No. 4, December 1953, pages 577-600.

"In the summer of 1952, 84 'normal' women were examined at the Laboratory of Physiological Hygiene, University of Minnesota. The overall study was designed to evaluate changes in body composition, with special reference to the fat content, and paralleled similar work on men (Brozek, J. Changes in Body Composition in Man During Maturity and Their Nutritional Implications). Skinfold thickness was measured at 10 sites with spring calipers and the fat content of the body was estimated from specific gravity. The body form of these women was appraised by inspection.

"Three age groups were studied (18-30, 31-45, and 46-67 years). Pronounced age differences in the amount and distribution of soft tissues were noted. The 'normally' proportioned body forms, with moderate amounts of fat harmoniously distributed, became less frequent in the older groups while harmoniously obese forms increased. Physiques showing an abundance of soft tissue in the extremities and lower parts of the body decreased in the older groups, while women with considerable fat on the trunk, breasts, upper arms, chest, and trochanters increased.

"Although the patterns of subcutaneous fat distribution changed, and in most instances showed an overall increase, the 'inner fat' seemed to increase more than the amount of the subcutaneous fat. Perhaps the rate of accumulation of inner fat - a phenomenon quite inaccessible to traditional anthropometry - will prove to be a useful criterion of aging in future nutritional and constitutional investigations."

The article is 23 pages long and includes 10 tables and one figure. The bibliography lists 32 references.

TABLE 82 - 1

Age, Stature and Weight of the Three Groups

GROUP	N	RANGE	AGE		HEIGHT cm		WEIGHT kg		RELATIVE WEIGHT	
			M		M		M		M	
A	31	18–30	24.0	2.6	162.6	6.2	54.69	6.8	94.13	9.14
B	25	31–45	39.8	4.4	163.2	6.5	61.26	6.8	96.95	9.44
C	28	46–67	55.4	5.3	160.6	6.2	61.60	11.0	95.18	15.06

TABLE 82 - 2

Skeletal Frames (Eurysomatic-Leptosomatic Body Form)
Percentage Frequencies for the Three Age Groups

GROUP	N	E	EL	ELLE	LE	L
A	27	44.5	18.5	22.2	14.8	0.0
B	25	28.0	28.0	24.0	16.0	4.0
C	27	22.2	33.2	14.8	18.6	11.1

TABLE 82 - 3

Soft Tissue Development

GROUP	N	DEGREE OF HYPER-HYPOPLASIA				
		H	Hn	n	nh	h
A	28	3.6	3.6	57.2	10.7	25.0
B	25	16.0	32.0	32.0	16.0	4.0
C	27	14.8	37.1	25.9	11.1	11.1

TABLE 82 - 4

Weight of Subcutaneous Adipose Tissue as Percentage of Total Body Weight

GROUP	N	MEAN	RANGE
A	31	18.85	11.5–29.4
B	25	21.91	15.5–31.8
C	28	22.81	9.3–36.4

TABLE 82 - 5

Body Fat Compartments

GROUP	AGE	N	WEIGHT	TOTAL BODY FAT	SUBCUTANEOUS FAT	INNER FAT
			kg	*kg*	*kg*	*kg*
A	18–30	23	55.12	14.4	3.8	10.6
B	31–45	19	61.63	20.0	5.2	14.8
C	46–67	20	61.48	23.8	5.2	18.6

TABLE 82 - 6

Percentage Contributions of Regional Subcutaneous Fat Deposits to the Total Thickness of Subcutaneous Adipose Layer in the Female Series

SITE	A	B	C
Chin	4.0	3.8	4.2
Back	8.0	8.6	9.1
Chest	8.1	9.4	10.4
Side	4.2	6.2	6.6
Waist	8.0	9.0	8.6
Abdomen	14.3	13.1	14.6
Arm	11.3	11.0	11.1
Thigh	21.1	20.8	19.6
Knee	7.9	7.5	6.8
Calf	13.1	10.5	9.1
Percentage total	100.0	99.9	100.1
Total thickness (mm)	87.6	104.0	109.9

83. White, B. Charles, Paul J. Johnson and H.T.E. Hertzberg. Review of Escape Hatch Sizes for Bailout and Ditching. Technical Note WCRD 52-81, Aero Medical Laboratory, Wright Air Development Center, Wright - Patterson Air Force Base, Ohio, September 1952.

Purpose: "To review wartime specifications of escape hatches in terms of current and experimental flying equipment."

Subjects: Subjects (N = 7) ranging "from 5 feet 4 inches to 6 feet 1 inch in height, from 130 to 215 pounds in weight and from 16 1/2 to 19 1/2 inches in shoulder width were used in the experiments. These measurements represent a range in size from the 5th percentile to the 95th percentile of Air Force personnel."

Apparatus: "The mock-up for the tests consisted of a plywood panel having a large opening, the dimensions of which could be varied by means of movable slats." Either a vertical, horizontal, or any intermediate position escape hatch could be simulated. "

Two different kinds of clothing were worn.
A. Intermediate (Standard Issue).
B. Experimental, Very Heavy Flying Clothing (Arctic Conditions).
The Long Range Individual Survival Kit (SAC, E-1) and the Seat Survival Kit (A-1) were also employed in the studies.

Procedure: "Each of the simulated bail-out and ditching tests was begun by a check of the adequacy of the present hatch sizes by subjects wearing the full flying equipment in present use. The hatch opening, if too small, was then enlarged until it was adequate. The entire procedure was then repeated with the subject wearing experimental arctic clothing, which is considerably more bulky than present equipment. First the A-1, then the E-1 survival kit was used with each trial."

Conclusions:
"1. The present standard sizes of 20 by 31 inches for the side hatch and 20 by 29 inches for the bottom hatch have been shown to be adequate for use with either the current equipment or the new experimental heavier clothing, provided no tunnel is involved, or the access area is not obstructed.

"2. The standard size of the top hatch should be increased to 22 by 22 inches and there should be a step or ledge not more than 45 inches below the lowest edge of the hatch to give additional leverage to shorter crew members."

The article is four pages long. There are no tables or figures. There are two references.

84. Woodson, W.E. A Study of Seating as Related to Electronic-Equipment Operators. Report 436, U.S. Navy Electronics Laboratory, San Diego, California, 9 April 1954 (ASTIA No. AD-39882).

This study investigated seating problems of shipboard electronic-equipment operators. "A comprehensive survey of past and present chair design was made to establish functional characteristics of good seating for Navy electronics operators. On the basis of functional requirements and analysis of previous studies of seating in other fields, an experimental chair was designed and studied both in the laboratory, with a pitch and roll apparatus, and at sea. Various tests and modifications of this chair provided data for recommending functional and dimensional requirements for adequate operator seating aboard ship. Emphasis in the study was placed on sonar equipment."

It was concluded that:
"1. Present chair designs are not adequate for all sonar, radar, and communications operators' positions. A single universal chair does not appear to be feasible for all types of installations or purposes.

"2. Certain features of chair design (such as seat cushion, arm rests, and back rests) should be standarized. Such items could be mounted on interchangeable mounts according to console and space requirements.

"3. Special design features for maintaining body stability should be incorporated in all chairs of this type which are to be used aboard ships of destroyer size or smaller."

The general requirements for adequate seating are considered to be: "(1) proper support of the body; (2) appropriate size of seat components; (3) satisfactory adjustment features; (4) suitable contouring and padding; and (5) security in relation to structural rigidity and body stability." Photographs are included of the experimental chair and its modifications. The graphic recommendations for the proposed standard seat assembly for equipment operators and seat and control relationships, from the report, are presented in the annotation.

This 20 page report includes 13 figures and a bibliography of 32 references.

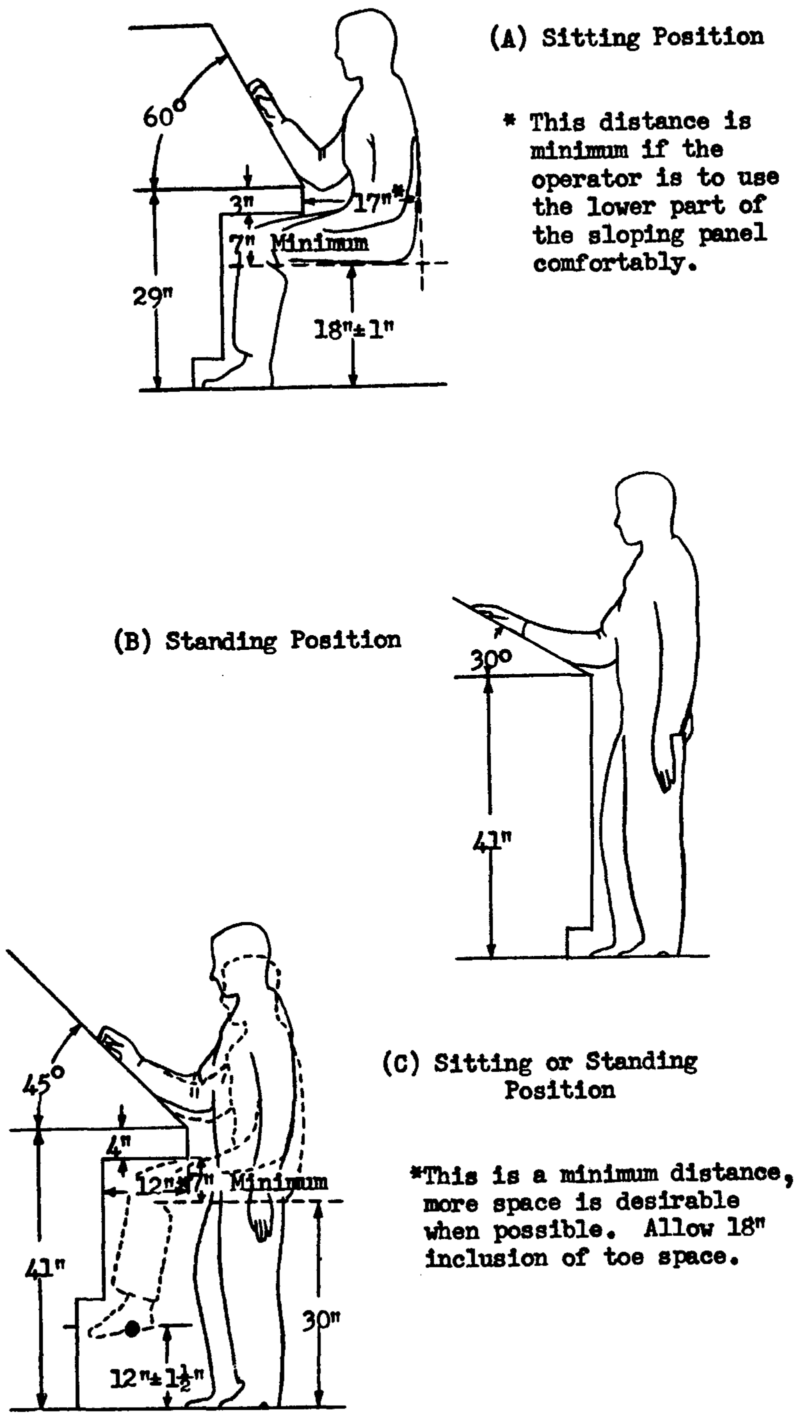


FIGURE 84 - 1

Seat and Console Relationships

PROPOSED STANDARD SEAT ASSEMBLY FOR EQUIPMENT OPERATORS

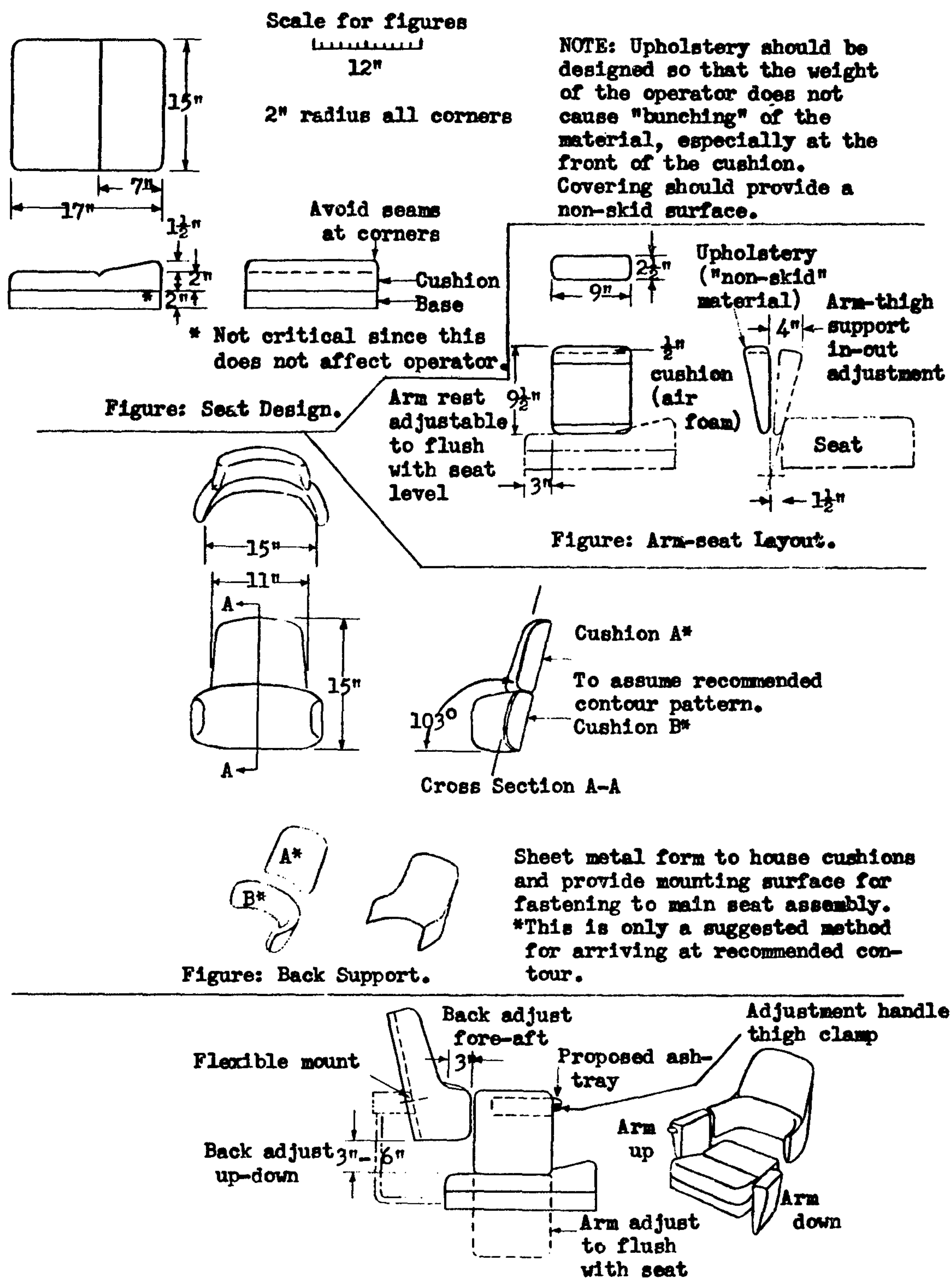


FIGURE 84 - 2

Seat Assembly

85. Batch, Joseph W. Measurements and Recording of Joint Function. United States Armed Forces Medical Journal, Volume 6, No. 3, March 1955, pages 359-382.

This article elaborates and illustrates the method described by Cave and Roberts for the measuring and recording of joint motion (Cave, E.F. and S.M. Roberts. Method for Measuring and Recording Joint Function).

"As pointed out by these authors: '(1) All motions should be measured by degrees from a neutral point of zero. (2) The neutral point from which motion is measured must be defined. (3) It is always worth while to mention the comparative motions in the joint of the opposite limb. (4) Angles should be measured with a goniometer or protractor. (5) Motions of joints above and below the affected part should be measured.'"

"The ranges of motion cited in this article are considered average for each joint as stated but may vary slightly from other published figures. In principle, the method employed and the measurements recorded are similar to those on Standard Form 527, Bureau of the Budget, May 1950. It differs in that each movement of each joint is recorded as such and the average limits of that movement are recored in a more detailed and complete manner.

"Both the active and passive range of motion should be accurately measured in degrees, using a goniometer, and the results recorded on a form.

"Some methods of measuring a type of joint motion ascribe a range greater than 180°. Such a measurement is unphysiologic and consists of combining two separate types of motion. For example, to state that the wrist extends from 110° to 245° is including a return from volar flexion to the extended position of 180° plus including the range of dorsiflexion of the wrist. In like manner, to state that the hip extends to 225° is including the range of hyperextension of the hip. When, for one reason or another, a joint cannot return to its normal extended, neutral, or zero position, it should be recorded as so many degrees of permanent flexion, abduction, and so on for each type of joint motion.

Neck

"The neutral position for the neck is with the head up and the chin in, which corresponds to the extended position of zero degrees (Figure 85 - 2).

"Movements. From the neutral position, movements which take place are rotation, flexion, hyperextension, lateral bending, and circumduction. Rotation to the right and left takes place primarily at the articulation between the first and second cervical vertebrae and to a lesser degree in the articulations between the remaining cervical vertebrae. Flexion, or forward bending; hyperextension, or backward bending; and lateral bending to the right and left are a result of the sum of motion in articulations between the skull and all the cervical vertebrae in the sagittal and coronal plane; circumduction, a succession of all the above movements.

"Position and Measurement. The patient is seated on a chair with his back to the examiner.

"Rotation is obtained by having the patient turn his head to the right and look first over his shoulder, then to the left and look over the other shoulder. Rotation is measured as the angle formed by a line on the sagittal suture of the skull rotating at the axis of the neck. The average limit of rotation is 55° to the right and to the left.

"Flexion is obtained by bowing the head forward and placing the chin on the chest. Flexion is measured as the angle formed by the forward bending of the head from the neutral position. The average limit of flexion is 40°.

"Hyperextension is obtained by bending the head backward so the patient is looking at the ceiling. Hyperextension is measured by the angle formed by the backward motion of the head from the neutral position. The average limit of hyperextension is about 50°.

"Lateral bending is obtained by bending to the right, then to the left, approximating the corresponding ear to the shoulder. Lateral bending is measured by the angle formed at the axis of motion by the new position of the neck from the neutral position. The average limit of lateral bending to the right and to the left is about 40°.

Spine

"The neutral position for the spine is with the patient standing erect evenly on both feet; with knees straight; hips, pelvis, and shoulders level; abdomen in; chest out; pelvis rotated in under vertebral column; chin in; head up, with a perpendicular line of weight bearing passing through the mastoid process across the greater trochanter and tibial tuberosity to the base of the fifth metatarsal. The lumbar and dorsal portions of the spine are practically flat, although the curves can be identified. There is no marked lateral curvature although, normally, there may be a slight lateral curvature with the convexity to the right. The Achilles tendons are perpendicular to the ground.

"Movements. From the neutral position, motions of the spine are flexion, hyperextension, lateral bending to the right and left, rotation to the right and left (Figure 85 - 3), and circumduction. These motions are a result of the sum of motions which take place at the articulations between each of the vertebrae in the sagittal, coronal, and transverse planes respectively. Because of this, accurate measurement is difficult. Motions should be compared with the normal for the individual person, considering age and habits. Alterations in the lumbar and dorsal curves should be noted in both the posteroanterior and lateral planes to determine flattening or reversal of these curves.

"Position and Measurement. Motions of the spine should be examined with the patient in the standing, sitting, and lying positions. The sitting position removes the influence of the ham-string muscles on the pelvis. The lying position aids in more accurate localization of pain and an evaluation of muscle tone.

"Flexion is obtained by having the patient bend forward to the limit of function. Flexion is measured by the angle formed by the spine at the axis of motion by the new position of the spine from the neutral position. The average limit of flexion of the spine is about 70°.

"Hyperextension is obtained by the patient bending backward to the limit of function. It is measured by the angle formed at the axis of motion by the backward bending of the spine from the neutral position. The average limit of hyperextension is about 30°.

"Lateral bending is obtained by having the patient bend to the right and to the left to the limit of motion. It is measured by the angle formed by bending the spine to the right and to the left from the neutral position. The average limit of lateral motion to the right or to the left is about 40°.

"Rotation is obtained by the examiner fixing the pelvis with his hands and having the patient rotate the body to the right and to the left. It is measured by comparing the angle made by plane of the shoulders with that of the pelvis. The average limit of rotation of the spine to the right or to the left is 35°.

Shoulder

"The neutral position for the shoulder is with the spine erect and the arms hanging straight down by the sides. This corresponds with the extended and adducted position of zero degrees.

"Movements. From the neutral position, motions which take place are abduction, lateral elevation, flexion, forward elevation, hyperextension, internal and external rotation in the neutral position, internal and external rotation in abduction (Figure 85 - 4), adduction, and circumduction. Movements at the shoulder joint take place between the head of the humerus and glenoid cavity of the scapula together with scapulothoracic, acromioclavicular, and sternoclavicular motion. Once 30° of abduction or 60° of forward flexion is obtained, the relationship of humeroscapular motion remains constant of two humeral to one part scapular motion. Four degrees of elevation of the clavicle takes place for every 14° elevation of the arm up to 90° and none thereafter. About 20° of motion takes place in the acromioclavicular joint throughout the course of abduction. The clavicle rotates upward and backward and the scapula downward and outward during abduction. At the sternoclavicular joint, the clavicle elevates 56°, retracts backward 25°, and rotates 50° on its longitudinal axis.

"Position and Measurement. The patient may stand erect or be seated to examine movement of the shoulder joint. For convenience of the examiner and to evaluate movement in the shoulder, the forearm is flexed to 90°.

"Abduction is obtained by raising the arm straight out and up from the side, and is measured by the angle formed by movement of the arm from the neutral position. The average limit of abduction is 90°.

"Lateral elevation is obtained by continuation of the upward movement of the arm above full abduction of 90° to the limit of motion. This motion is primarily a result of scapulothoracic motion. The average limit of lateral elevation is 40° beyond the 90° of abduction.

"Flexion of the shoulder is obtained by raising the arm straight forward and upward from the neutral position. The average normal limit of flexion is 90°.

"Forward elevation is obtained by a continuation of the upward movement of the arm. In the completely elevated arm, the clavicle rotates 40° in its longitudinal axis. The average limit of forward elevation is 90° beyond the 90° of flexion.

"Hyperextension is obtained by moving the arm backward from the neutral position. The angle formed by the movement of the arm from the neutral position is measured. The average limit of hyperextension is about 45°.

"Internal rotation of the shoulder in the neutral position is facilitated by flexing the forearm to 90° and turning the forearm inward. Complete internal rotation can be obtained by placing the forearm behind the back. This motion is measured by the angle formed by the forearm moving from the neutral position. The average limit of internal rotation with the shoulder in the neutral position is 90°.

"External rotation of the shoulder in the neutral position is obtained as for internal rotation except that the forearm is turned outward and the angle formed by the forearm in moving from the neutral position is measured. The average limit of external rotation of the shoulder in the neutral position is 45°.

"Internal rotation of the shoulder in the abducted position is obtained by flexing the forearm to 90° to facilitate the movement and its evaluation, the arm is abducted, and the forearm moved downward. The angle formed by the forearm in moving from the starting position is measured. The average limit of internal rotation with the shoulder abducted is 90°.

"External rotation of the shoulder in the abducted position is obtained as for internal rotation except the forearm is moved upward and the angle formed by the forearm moving from the starting position is measured. The average limit of external rotation of the shoulder in the abducted position is 90°.

"Adduction of the shoulder is obtained by moving the arm toward the midline from the neutral position. In the neutral position adduction is prevented by the side of the body, however, about 10° of adduction can be obtained by placing the arm in front or rear of the body.

"Circumduction is accomplished by moving the arm in an arc about the shoulder. It is a succession of the above movements and results in describing a complete circle.

Elbow

"The neutral position for the elbow joint is with the forearm extended and the hand in midposition.

"Movements. From the neutral position, movements of the elbow joint are flexion, hyperextension, supination, and pronation (Figure 85 - 5). Flexion and hyperextension occur between the humerus with the radius and ulna. Supination and pronation occur between the radius and ulna and the radius with the humerus.

"Position and Measurement. Flexion is obtained by forward bending of the forearm on the arm. The angle formed by the forearm moving from the neutral position is measured. The average limit of flexion is 145°.

"Hyperextension occurs in the same plane as flexion, only it is obtained by moving the forearm backward on the arm from the neutral position and measuring the angle so formed. Normally, there is no hyperextension at the elbow.

"Supination. The forearm is placed with the ulnar border of the hand down and the radial border up. Supination is obtained by rotating the forearm outward with the palm of the hand being turned up. This motion takes place between the proximal and distal radioulnar and the radiohumeral articulations. The angle formed by this rotation from the neutral position is measured. The average limit of supination is 90° at the hand, and 60° if measured at the wrist.

"Pronation is measured from the same neutral position as for supination. It is obtained by rotating the forearm inward, turning the palm down. The angle formed by rotation of the forearm and hand from the neutral position is measured. The average limit of pronation is 90° at the hand and 75° if measured at the wrist.

Wrist

"The neutral position for the wrist is with the hand extended in line with the forearm with the palm down.

"Movements. From the neutral position, movements of the wrist joint are palmar flexion, dorsiflexion (dorsiextension), ulnar and radial deviation, pronation, and supination. A degree of circumduction is possible at the wrist which is a combination of the above movements. These movements occur primarily between the carpus and radius except that pronation and supination occur primarily at the articulations between the radius and ulna.

"Position and Measurement. The wrist is placed in the neutral position with the hand in line with the forearm and with the palm down.

"Palmar flexion is obtained by bending the hand downward at the wrist. The angle formed by this movement of the hand from the extended neutral position is measured. The normal limit of palmar flexion is 70°.

"Dorsiflexion is obtained by bending the hand upward at the wrist from the neutral position. The angle so formed is measured. The normal limit of dorsiflexion is 65°.

"Ulnar deviation is obtained by bending the hand toward the ulnar side. The angle formed by a line down the third finger deviating from the neutral position at the wrist is measured. The average limit of ulnar deviation is 30°.

"Radial deviation is obtained by deviating the hand to the radial side from the neutral position and the angle so formed measured as for ulnar deviation. The average limit of radial deviation is 15°.

"Pronation and supination are measured as referred to under the elbow measurements.

Fingers

"The neutral position for measurement of the finger motion is with the fingers extended (Figure 85 - 7). Each joint should be measured for flexion and examined for lateral stability. Flexion is the only motion recorded for each joint. The normal limits of motion are 45° for the distal interphalangeal joints, 110° for the proximal interphalangeal joints, and 90° for the metacarpophalangeal joints. If hyperextension exists, it should be measured and recorded.

"The neutral position for the thumb is with the thumb extended alongside of the index finger which is also the adducted position. The motions of the thumb are abduction, flexion of interphalangeal and metacarpophalangeal joints, hyperextension, and opposition. Abduction is the radial displacement of the thumb from the index finger and is measured as the angle formed between the thumb and the index finger which normally is 40°. Flexion is the forward bending of the joints of the thumb and normally there is 45° of motion at the interphalangeal joint and 45° at the metacarpophalangeal joint. Hyperextension of the thumb is possible, normally, so that the tip of the thumb is one inch behind the plane of the dorsum of the hand. Opposition of the thumb is that motion produced by rotation of the thumb in an ulnar direction. Normally, it can be carried to a point where the tip of the thumb reaches a point three inches in front of the base of the third finger.

Hip

"The neutral position for the hip joint is with the lower extremities in the extended position as in a man standing erect.

"Movements. From the neutral position, movements of the hip joint are flexion, hyperextension, abduction, adduction, internal and external rotation in extension, internal and external rotation in flexion, and circumduction (Figure 85 - 8). Movement takes place between the head of the femur and the acetabulum.

"Position and Measurement. For ease of examination, the patient is placed supine on an examining table. All movements except hyperextension, which is performed in the prone or lateral position, can be determined in this position. Abduction may also be performed in the lateral decubitus position.

"Flexion. With the patient lying flat on his back with his legs straight, flexion is obtained by bringing the thigh forward and upward toward the abdomen. The angle formed by the thigh moving from the neutral position is measured. The average limit of flexion of the hip is 120°.

"Any limitation of complete extension of the hip should be recorded in degrees of permanent flexion. In order to obtain this measurement, with the patient supine, the opposite hip is flexed on the abdomen until the lumbar vertebrae are flat with the table. The angle formed by the femur with the horizontal line representing the neutral position is recorded as degrees of permanent flexion.

"Hyperextension is obtained with the patient lying prone or in the lateral decubitus position. The thigh is moved backward from the neutral position. The angle formed by this movement from the neutral position is measured. The average limit of hyperextension is 45°.

"Abduction is obtained either in the lateral decubitus or supine position. The thigh is moved outward from the neutral position. The angle formed by this movement from the neutral position is measured. The average limit of abduction is 45°.

"Adduction is obtained by moving the thigh across the midline from the neutral position. The angle so formed by this movement is measured. The average limit of adduction is 40°.

"Internal rotation in extension can readily be obtained with the patient in the prone position. The knee is flexed to 90° and the leg and foot rotated outward. The angle formed by the leg moving from the vertical neutral position is measured. The average limit of internal rotation in extension is 20°.

"External rotation in extension is obtained in a manner similar to that for internal rotation except the leg and foot are rotated inward. The angle formed by the leg moving from the neutral position is measured. The average limit of external rotation in extension is 35°.

"Internal rotation in flexion. With the patient supine the hip and knee are each flexed to 90°, the leg and foot are rotated outward. The angle formed by the leg moving from the neutral position is measured. The average limit of internal rotation in flexion is 30°.

"External rotation in flexion is obtained in a manner similar to internal rotation except the leg and foot are rotated inward and the angle so formed measured. The average limit of external rotation in flexion is 60°.

"Circumduction of the hip is a succession of the above movements obtained by describing an arc with the thigh through the extremes of the various movements of the hip joint.

Knee

"The neutral position for the knee joint is with the leg in a straight line with the thigh in the extended position (Figure 85 - 9).

"Movements. From the neutral position movements of the knee are flexion and hyperextension. These movements occur at the articulation between the femur and the tibia. In addition to these movements lateral and anteroposterior stability of the knee joint should be tested.

"Position and Measurement. These movements may be measured with the patient sitting on the edge of an examining table or lying supine on the table.

"Flexion is obtained by bending the leg backward toward the posterior surface of the thigh. In the supine position, this is facilitated by flexion of the hip. The angle formed by the leg moving posterior from the neutral position is measured in degrees. The average limit of knee flexion is 135°.

"Hyperextension is obtained by holding the thigh firm on the examining table and lifting the leg anteriorly from the neutral position. The angle formed by movement of the leg from the neutral position is measured and recorded. There is normally no hyperextension of the knee joint.

"Lateral stability is obtained by moving the leg first laterally then medially from the neutral extended position. Any deviation should be recorded as mild, moderate, or severe. This is a test for the medial and lateral collateral ligaments of the knee.

"Anteroposterior stability is obtained by flexing the knee to 90° to relax the collateral ligament. The leg is grasped and pulled directly anterior. This is a test of the status of the anterior cruciate ligament. The leg is returned to its normal position and the leg then pushed posteriorly to test the stability of the posterior cruciate ligament. Abnormal motion is recorded as mild, moderate, or severe.

Ankle

"The neutral position for the ankle is with the lateral border of the foot at 90° with the axis of the leg and in midposition as regards to inversion and eversion (Figure 85 - 10).

"Movements. From the neutral position the movements of the ankle are plantar flexion and dorsiflexion (extension). These movements take place at the articulation between the tibia and talus and should be compared with the knee in the extended position and with the knee flexed at 90° to rule out limitation of motion due to a tight gastrocnemius or soleus muscle.

"Position and Measurement. The patient may be sitting or lying supine on the examining table.

"Plantar flexion is obtained by moving the foot downward from the neutral position. The angle formed by the lateral border of the foot moving from the neutral position is measured in degrees of plantar flexion. The average limit of plantar flexion of the ankle is 35°.

"Dorsiflexion of the ankle is obtained by moving the foot upward from the neutral position. The angle formed by the lateral border of the foot moving from the neutral position is measured in degrees of dorsiflexion. The average limit of dorsiflexion is 20°.

Foot

"The neutral position for the foot is with the os calcis in neutral position as regards inversion and eversion and with a line bisecting the heels, extending through the second toe perpendicular to a line representing the posterior surface of the heel (Figure 85 - 11).

"Movements. Movements of the foot are inversion and eversion which occur in the subtalar joint; adduction and abduction which take place in the midtarsal joints; flexion and hyperextension of the metatarsophalangeal joints, which in the great toe is the most important; and interphalangeal joint motions of flexion and hyperextension which are very difficult to measure.

"Position and Measurement. Inversion is the inward deviation of the os calcis which normally is 35°. Eversion is the outward deviation of the os calcis and can normally be carried to 25°. Adduction is the inward deviation of the forefoot from the neutral position and normally is about 5°. Abduction is the outward deviation of the forefoot which is also about 5°. Metatarsophalangeal and interphalangeal joint motion is of little importance except in the great toe where, normally, it is 35° of flexion and 20° of hyperextension. Pronation of the foot is a combination of eversion and abduction which may normally be 15°. Supination is a combination of inversion and adduction and normally is 20°.

"The method of recording joint motion described simplifies the procedure by considering only one function of the joint. The extended position is considered the zero and not measured as a joint function and all motion is measured from this neutral point. Failure to extend to this zero or neutral point is recorded as so many degrees of permanent flexion. The confusion of recording several readings is eliminated, for example: instead of recording, 'the elbow flexes from 180° to 60° and extends from 60° to 180°,' it is recorded as: 'the elbow flexes 120°, no permanent flexion.' In those patients where limitation of motion may exist, a report might read, 'the elbow flexes from 20° to 100°; 20° of permanent flexion.' Further, the confusion of ascribing more than 180° to any one motion which is not physiologically possible is eliminated. Each functional motion of the joint is recognized and measured."

The report is 23 pages long. One table (a suggested form for recording joint measurements) includes some data on joint motion, but the N and other essential characteristics of the subjects are not specified. There are 11 figures which define the taking of the measurements pictorially. A bibliography of five references is included.

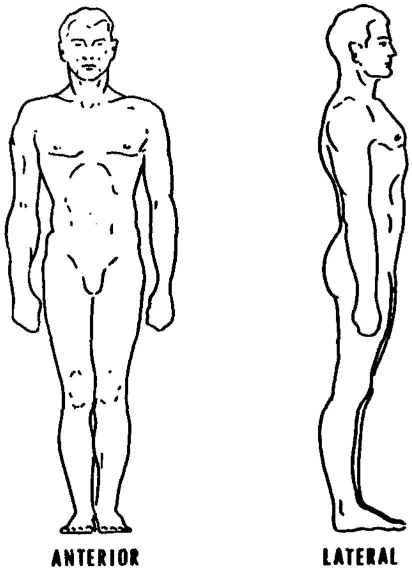


Figure 1. Anatomic neutral position.

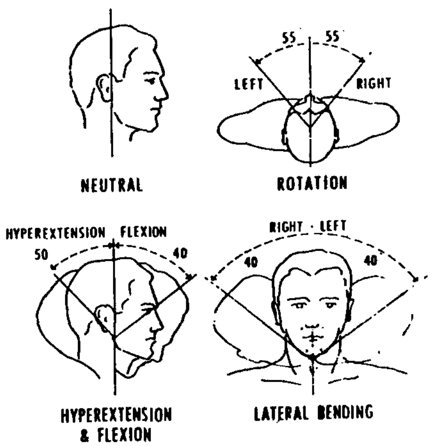


Figure 2. Average normal range of motion of the neck.

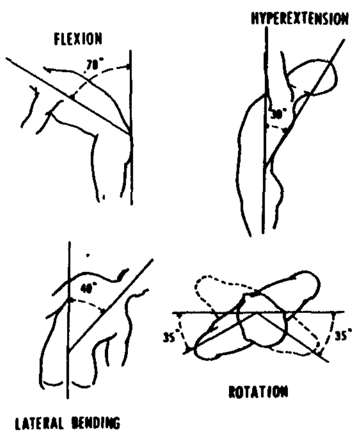


Figure 3. Average normal range of motion of the spine.

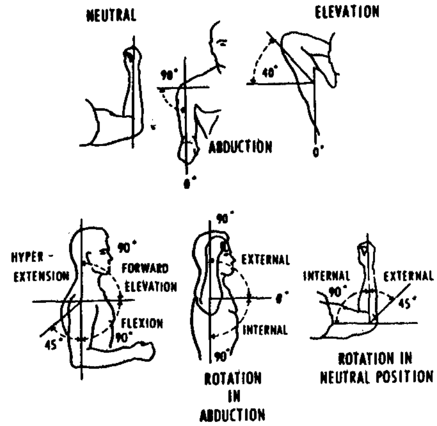


Figure 4. Average normal range of motion of the shoulder.

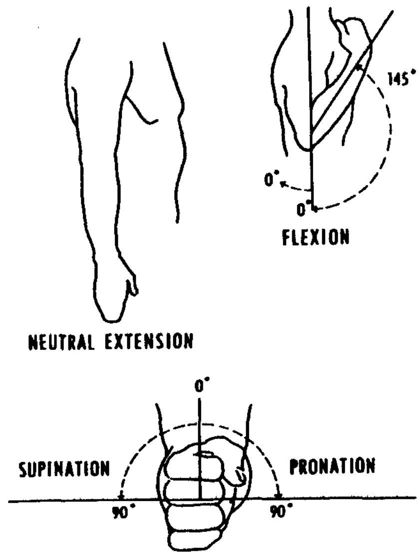


Figure 5. Average normal range of motion of the elbow.

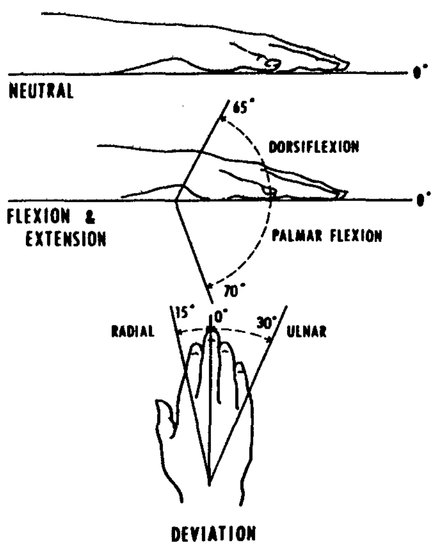


Figure 6. Average normal range of motion of the wrist.

FIGURES 85 - 1 to 85 - 6

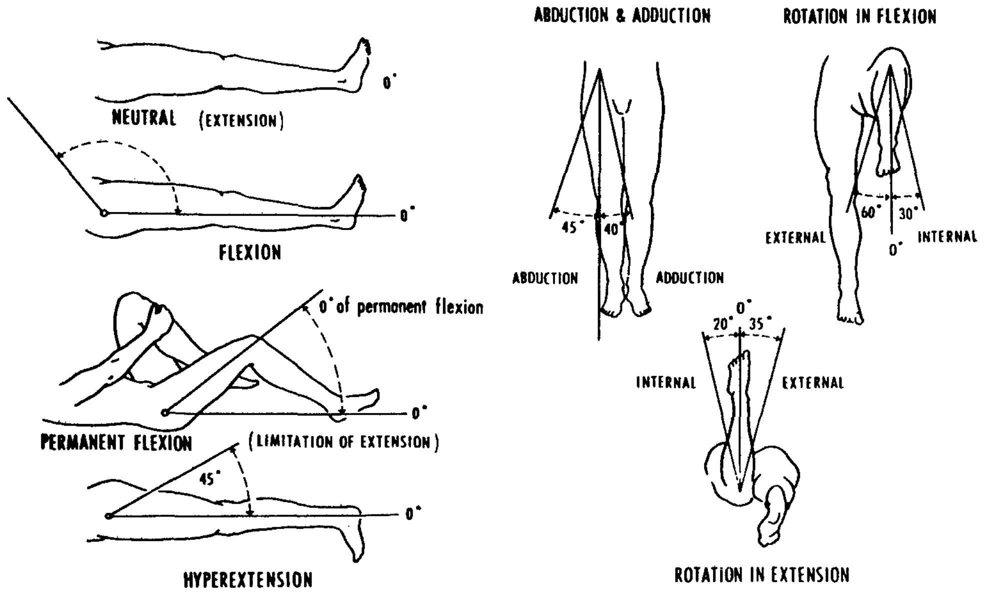


Figure 8. Average normal range of motion of the hip.

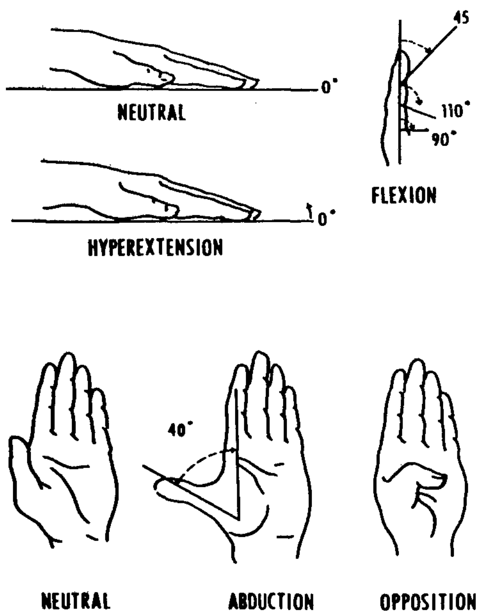


Figure 7. Average normal range of motion of the finger.

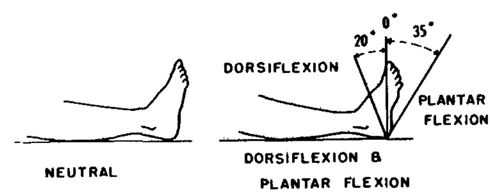


Figure 10. Average normal range of motion of the ankle.

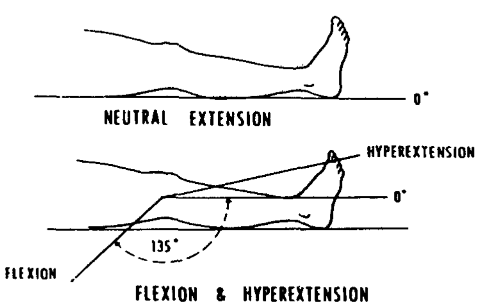


Figure 9. Average normal range of motion of the knee.

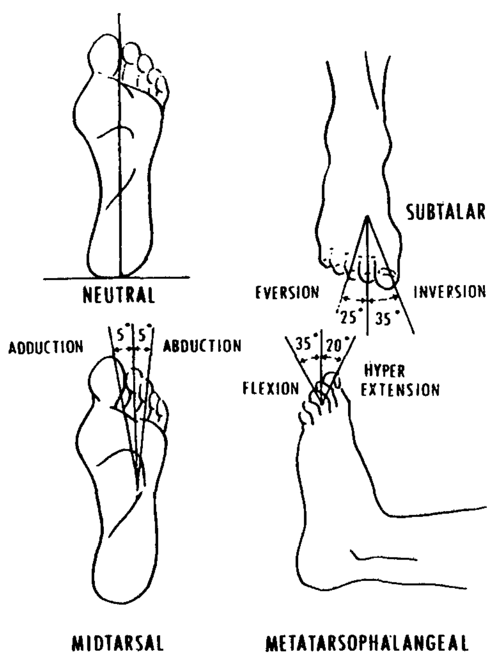


Figure 11. Average normal range of motion of the foot.

FIGURES 85 - 7 to 85 - 11

86. Blaschke, Alfred C. and Craig L. Taylor. The Mechanical Design of Muscle-Operated Arm Prostheses. Journal of the Franklin Institute. Volume 256, No. 5, November 1953, pages 435-458.

"The harnessing of human muscle to operate mechanical apparatus, such as a cineplastically controlled prosthesis, introduces a novel and significant problem in engineering design. It includes: first, study and measurement of the properties of the muscles concerned; second, an idealization of these properties by introducing an order of approximation suited to the practical problem of utilization; third, definition of the utility requirements; and fourth, design of a mechanical system which matches the idealized properties to the utility requirements. ...After surgery and healing, the cinetized muscle toughens from training and use and is fitted with a pin to which is attached a cable operating the artificial prehension device. ...This paper is devoted to the principles of design associated with this harnessing of a muscle 'motor'. ...The analysis proceeds on the assumption of a linearized biceps muscle force-length diagram. Four types of mechanical lever systems are proposed to compensate for the loss in muscle force with excursion. Design principles are established for each system and the performance of typical designs are compared."

The article is 23 pages long and contains three tables, 13 figures, 17 major formulas, two appendices, and a bibliography of 11 references.

87. Brown, C.W., E.E. Ghiselli, R.F. Jarrett, E.W. Minium, and Robert M. U'Ren (University of California). Magnitude of Forces which may be Applied by the Prone Pilot to Aircraft Control Devices. 1. Three-Dimensional Hand Controls. Memorandum Report MCREXD-694-4J, U.S.A.F., Wright-Patterson Air Force Base, Engineering Division, Ohio, 4 March 1949 (ASTIA No. ATI-52794).

"Sixty-three men with service pilot experience and two non-pilots (Total N = 65) were tested on a three-dimensional hand-control device suitable for use as a control for a prone-flown plane. The maximum forces which they could apply to the controls in each of six directions of nine bed-positions and in the seated position were measured."

"As was expected, large individual differences were observed. In certain of the directions in which the subjects were required to apply force the prone position was, on the average, superior to the seated position. In certain other directions the seated position was superior. The relative superiority of the prone position in those directions in which it was superior was as great as the relative superiority of the seated position for its most advantageous directions."

Apparatus: The apparatus, as finally evolved, possessed the following characteristics. It was physically stable and sturdy. It permitted three types of movement: push-pull, right-left turn, and right-left (clockwise or counterclockwise) twist. It permitted minimal control movement under force (it was nearly isometric). The device permitted the ready alteration of the subject's position with reference to the controls in both the horizontal and vertical planes. The apparatus could easily be converted from prone to seated use.

For use in the prone position, the subject lay on a slightly inclined bed, head end elevated. A chest support, tilted upwards 20 degrees from the bed, permitted the subject to employ horizontal forward vision with only a slight raising of the head at the neck. "Thus a position of the subject was achieved which other investigators (Clark, W.G., Henry, J.P., Greeley, P.O. and Drury, D.R. Studies on Flying in the Prone Position) have suggested should be realized for prone position flying."

Three positions were employed: near position, in which the shoulders were 9 inches from the vertical plane of the handlebar grips; middle position, in which this distance was 13 inches; far position, in which the distance was 17 inches.

"The bed platform was hinged at the rear, so that the bed could be raised or lowered in order to change the effective height of the shoulders of the subject in respect to the two control points. Three positions of elevation were on a level with the points to which the forces were applied to the handlebar grip, in the middle position the shoulders were 5 inches above these points, and in the high position

10 inches above them. It will be noted that the method of changing elevation makes changes in the tilt of the subject's position. In the low position, the bed itself is tilted 3 degrees from the horizontal, in the middle position 6 1/2 degrees, and in the high position 10 degrees. In each case the tilt is supplemented by the 20 degree tilt of the chest support and the upward movement of the subject's head and eyes. It is thought that changes in bed angle necessitated by changes in elevation of the shoulders will not result in significant differences in the implications of the data of the present study insofar as the realization of horizontal vision is concerned."

For use in the seated position, the bed was placed in the low (3 degree) position as used for the prone position. The chest support was taken away and a board was fastened perpendicular to the bed and 16 inches from the forward edge of it. The front part of the bed thus served as a seat with the board acting as a back rest. The centers of the control grips were 11 1/4 inches above the seat. The distance of the control grips forward of the front edge of the seat was 20 3/4 inches. This arrangement is similar to that in standard cockpits except that the present controls are some 8 inches lower than wheel type controls and 3 inches lower than the typical stick control. The seat was 18 inches above the floor. Foot supports were located on the floor 20 inches in front of the seat.

The control column and measurement system was arranged as follows: A standard bicycle handlebar assembly (hand grips 16 inches apart) was used, the center of rotation in line with the grips. The radius of rotation was 8 inches. "The tube and bearing of the assembly were mounted on an upright post forming the vertical part of the control column. The post was pivoted at its base to the forward end of a horizontal member, which extended backward beneath the bed to a point 22 inches from the post. At this point the horizontal member was secured by means of a pivot. The handlebar assembly was adjusted so the hand grips were located between the bed and the post at a point 6 inches behind the post. The effective radius of movement for the right-left turn, the distance between pivot point and hand grips was then 16 inches and not 22 inches." Locking mechanisms were attached which prevented motion in more than one dimension at a time during the tests. Thus, the man could (1) move the control column forward and backward, (2) move the control column laterally (by the application of force to the handlebars), or (3) twist the handlebars in a clockwise or counterclockwise direction. The forces applied were transmitted by means of cables over pulleys to a lever on the plunger of a hydraulic cylinder. The pressure operated a calibrated pressure gauge; readings at low pressure were to the nearest pound and, at high pressures, to the nearest five pounds.

The push-pull and also the right-left turn movements were not truly rectilinear, but described small amounts of arc; since the displacement of the controls never exceeded two inches, this feature is considered acceptable. During testing, each application of force began with the controls in a physically "neutral" position.

"In the case of the prone position, the position of the bed, in terms of both its vertical and its horizontal placement, was found to influence the magnitude of the forces which may be applied, but these influences are small.

"Since the relative advantage of the prone or seated position with such controls as have been investigated by us depends not alone on maximum forces applicable, but upon the control surfaces to be operated by these various directions of control movement, and upon the relative frequency in operational flight with which maximal application of force is required in each of the various dimensions, we have not attempted an evaluation of the relative advantage or disadvantage of the prone position in conjunction with controls of the type investigated. We find no very convincing evidence, however, that the prone position will be at a disadvantage over the seated position with respect to forces applicable to the controls; indeed, for some movements which might be most important in combat flight the prone position has a definite advantage.

"For the same reasons we are unable to discuss the relative over-all advantage or disadvantage of the prone position, but we have presented data necessary to the determination of that optimal position.

"We find that if such controls as those investigated are to be employed in prone flown aircraft, provision must be made to permit them to withstand forces applied by pilots of about 500 pounds in the push-pull dimension and of about 250 pounds in the other dimensions."

The report is 68 pages long and includes 18 tables and eight figures. The bibliography contains five items. Selected data are included.

TABLE 87 - 1

Personal Data on Experimental Subjects. N = 65

	Mean	Standard deviation
Height (inches)	70.7	2.3
Weight (pounds)	160.	15.
Age (years)	24.4	2.3
*Arm length (inches)	24.8	1.2

*Length of arm from top of clavicle to center of grip with arm extended upwards. (see description of method in text)

Pilot experience	N
Non-pilots	2
1-49 hours	7
50-99 hours	3
100-499 hours	10
500-999 hours	17
1000-1499 hours	15
1500-1999 hours	6
2000-5000 hours	5

	Preferred hand		
	Right	Left	Ambidextrous
N	58	6	1

TABLE 87 - 2

Maximum Strength: Means and Standard Deviations for Six Movements in Nine Bed Positions for Seated and Prone Positions. N = 65.

Mean Values

Movement	Low Bed Position			Middle Bed Position			High Bed Position			Prone	Seated
	Front	Middle	Rear	Front	Middle	Rear	Front	Middle	Rear	Means	
Push	114	127	199	132	148	231	134	191	194	163	242
Pull	262	256	257	259	262	257	237	240	237	252	199
R. Turn	112	106	92	123	107	95	113	103	85	104	88
L. Turn	107	103	89	115	102	90	111	94	80	99	86
R. Twist	139	127	108	126	116	101	127	115	96	117	152
L. Twist	138	129	111	128	117	100	131	116	94	118	151
Means	145.3	141.3	142.7	147.2	142.0	145.7	142.2	143.2	131.0	142.3	153.0

Standard Deviations

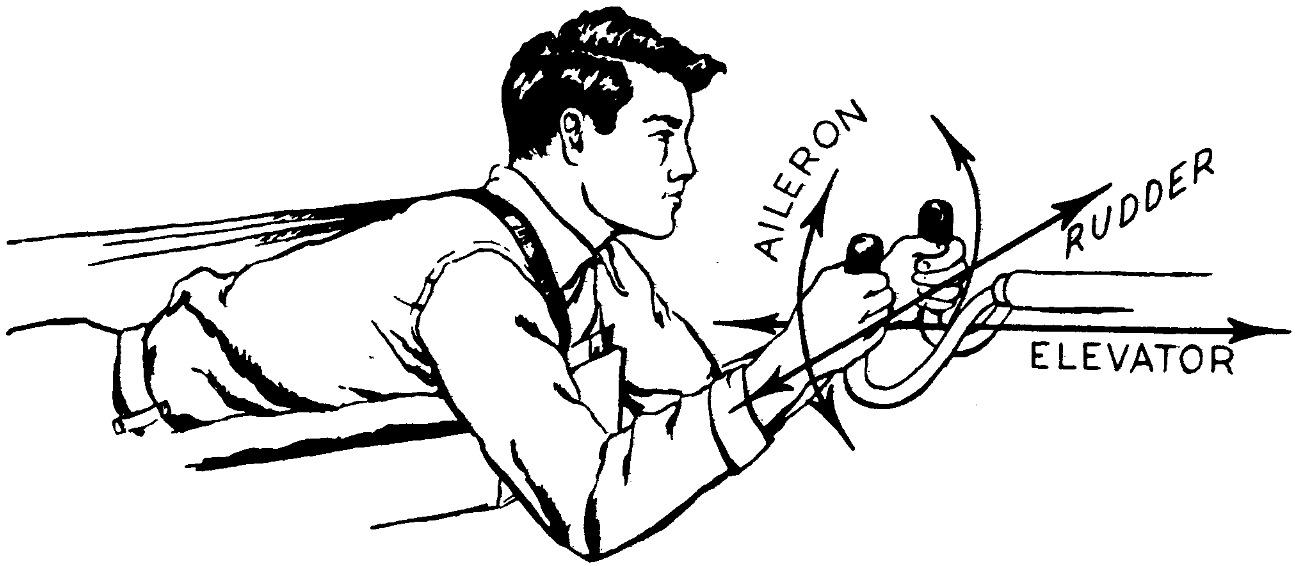
Movement	Low Bed Position			Middle Bed Position			High Bed Position			Seated
	Front	Middle	Rear	Front	Middle	Rear	Front	Middle	Rear	
Push	22.4	31.8	75.4	27.4	40.5	55.3	34.1	42.4	46.1	56.7
Pull	58.2	47.7	43.8	50.0	44.2	41.8	40.1	41.7	38.7	30.8
R. Turn	28.3	25.0	23.0	27.9	24.3	22.4	29.2	22.7	22.2	23.7
L. Turn	33.3	27.9	22.1	29.7	24.0	21.1	25.0	21.2	19.2	19.0
R. Twist	26.1	23.8	19.7	24.6	21.1	20.2	20.7	22.4	22.0	31.5
L. Twist	29.6	23.7	20.9	23.2	22.5	21.8	24.0	23.3	21.5	33.3

Table 2.--Maximum Strength: Means and Standard Deviations for Six Movements in Nine Bed Positions for Seated and Prone Positions. N = 65

TABLE 87 - 3

Maximum Strength: Mean Forces Applied in Each Movement Expressed as a Percentage of the Over-all Mean (all bed positions) for that Movement, Together with Over-all Mean Forces (in pounds) for Each Movement.
N = 65

Movement	LF	LM	LR	Bed Position MF	MM	MR	HF	HM	HR	Mean of all prone positions in pounds	Seated in relation to prone, in percentages
Push	70	78	122	81	91	142	82	117	119	163	148
Pull	104	102	102	103	104	102	94	95	94	252	79
Right Turn	108	102	88	118	103	91	109	99	82	104	85
Left Turn	108	104	90	116	103	91	112	95	81	99	87
Right Twist	119	109	92	108	99	86	109	98	82	117	130
Left Twist	117	109	94	108	99	85	111	98	80	118	128



Control dimension	Maximum control forces to be expected from pilots at point of grip (combined force of two hands): Strongest 1% of pilots	Average pilot	Weakest 1% of pilots
Elevator	439	262	85
Rudder	201	123	45
Aileron	209	139	69

FIGURE 87 - 1

Illustration of Three Prone Position Control Dimensions and the Maximum Forces which the Strongest, Average, and Weakest Pilots can be Expected to Apply to Such Controls.

88. Brown, C.W., E.E. Ghiselli, R.F. Jarrett, E.W. Minium, R.M. U'Ren (University of California, Berkeley, California). Magnitude of Forces Which May be Applied by the Prone Pilot to Aircraft Control Devices. 2. Two-Dimensional Hand Controls. AF Technical Report No. 5954, United States Air Force, Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio, October 1949. (Armed Services Technical Information Agency No. ATI-72377.)

The authors studied two kinds of hand-manipulatory control responses in the prone position: (1) rectilinear up-down, in which both arms move the controls in the vertical plane, the two arms moving up and down together, and (2) reciprocal forward-backward, in which a wheel-type motion is made in the horizontal plane, the two arms working reciprocally in the forward and backward direction (Figure 88 - 1).

The problem was to determine the force that a pilot in the prone position can exert on the controls in each of the two ways specified. Two categories of force were used: (1) maximal force, in which the subject applied as much force as possible, and (2) "reasonable" force, in which he retained unused a reserve of strength ("so that you feel you could retain control over the other movements, and be prepared to make emergency adjustments, as would be necessary in the flying situation").

The authors took measurements on the subjects at each of three positions of vertical and at each of three positions of horizontal adjustment with respect to the controls, making nine combinations in all.

"In adjusting the position of the subject relative to the controls, the control column remained stationary and the bed was moved relative to it. The bed was adjustable in the horizontal plane to permit three positions. In the forward position the horizontal distance from the forward point of the subject's shoulders to the center of the control grips was 9 inches, in the middle position this distance was 13 inches, and in the rear position it was 17 inches.

"Vertical adjustment was permitted by hinging the bed platform at the rear end and varying the height of the forward end. For the low position the center of the shoulders was on the same level as the center of the hand grips, in the middle position the shoulders were 5 inches above this point, and in the high position the shoulders were 10 inches above the same point. It should be noted that changing the vertical level of the bed platform by this means causes a change in the tilt of the subject's position. For the low, middle and high positions the angles of bed tilt were 3^{o}, $6\ 1/2^{o}$, and 10^{o}, respectively. The tilt of the chest support remained constant at 20 degrees relative to the bed. It was thought that these changes in bed angle would not result in significant differences in the implications of the data insofar as the realization of horizontal vision was concerned.

"An approach to isometric measurement was attained by having the movement of the controls limited to a maximum excursion of 1 1/2 inches. This prevented any change in the position of the subject relative to the controls due to displacement of the controls during the response.

"There were four experimental sessions, each lasting about 40 minutes. No more than three nor less than two sessions were given in any week.

"Four responses under the condition of maximum strength were obtained for purposes of computing reliability. These were followed by four 'reasonable' strength responses, one for each movement. Finally six regular trials on maximum strength responses were completed.

"During the first session then the subject performed four reliability trials, four 'reasonable' strength trials, and six regular maximum strength trials. During the three subsequent experiments sessions thirty regular maximum trials were completed. For the maximum strength condition each subject executed each type of movement in each bed position, making a total of thirty-six maximum strength trials, not counting the initial reliability trials.

"It was thought that any effect of one response upon those following it could be best controlled by purposely selecting a sequence in which each movement was least likely to be affected by the preceding movement, rather than be randomizing the order of movements..."

"For the thirty-six maximum strength trials the bed positions were randomized under the restriction that each bed position must appear once for each movement.

Students (N = 37) "at the University of California were used as subjects. All but two were pilots and most of the pilots were or had been military pilots. Seventy percent of these subjects also served in the previous strength of movement experiment reported as part 1 of this investigation... Because of the time involved, the subjects were paid a nominal sum for their services. Information on age, handedness and pilot experience was obtained, and height, weight and arm length were measured. The arm length was measured in the following manner. The subject in a seated position grasped a cylinder 1 1/2 inches in diameter and was then instructed to fully extend his arm vertically without straining. The distance from the outer end of the clavicle to the center of the cylinder was then measured. The value recorded was the mean measurement for the right and left arms.

"A comparison of the characteristics of the sample with similar characteristics available for aviation cadets... can be made from an examination of Table 88 - 1. In relation to cadets the mean age of the subjects is one year greater, the mean height falls at the 75th percentile of cadets and the mean weight falls at the 70th percentile of cadets. In terms of pilot exerience the group is very heterogeneous, flying time ranging from zero to more than 2000 hours. All but 8 had 100 or more hours of flying time."

"The amount of applied force for each of the four responses in the reasonable strength condition averaged about 50 percent of that obtained in the corresponding movement and position under the maximum strength condition.

"The two rotation responses gave very much higher maximum responses than did the two rectilinear responses. In seven of the nine bed positions the applied force for the down movement was greater than that for the up movement. In eight of the nine bed positions the applied force for the right rotary movement was greater than that for the left rotary movement.

"Variations in both horizontal and vertical position produced significant changes in the maximum force applied in each of the four kinds of movements."

The report is 19 pages long and includes eight tables and three figures. The report lists three references. An eight-page appendix is included in the report. The tables included in the annotation provide the main data of the report.

89. Brown, C.W., E.E. Ghiselli, R.F. Jarrett, E.W. Minium, R.M. U'Ren (University of California). Magnitude of Forces Which May be Applied by the Prone Pilot to Aircraft Control Devices. 3. Foot Controls. AF Technical Report No. 5955, United States Air Force, Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio, October 1949. (Armed Services Technical Information Agency No. ATI-70936.)

"The possibility that aircraft flown from the prone position may be controlled by some modification of conventional controls in which one dimension of control is mediated by rudder pedals; requires investigation into the problem of the amount of force which may be applied by the foot under conditions likely to be imposed by the prone position.

"The present study has been confined to the determination of the forces which may be applied in extension of the foot in each of five positions, as follows: when the foot is placed at right angles to the axis of the lower leg, and when it is placed at angles of 10 and 20 degrees on either side of the right angle position.

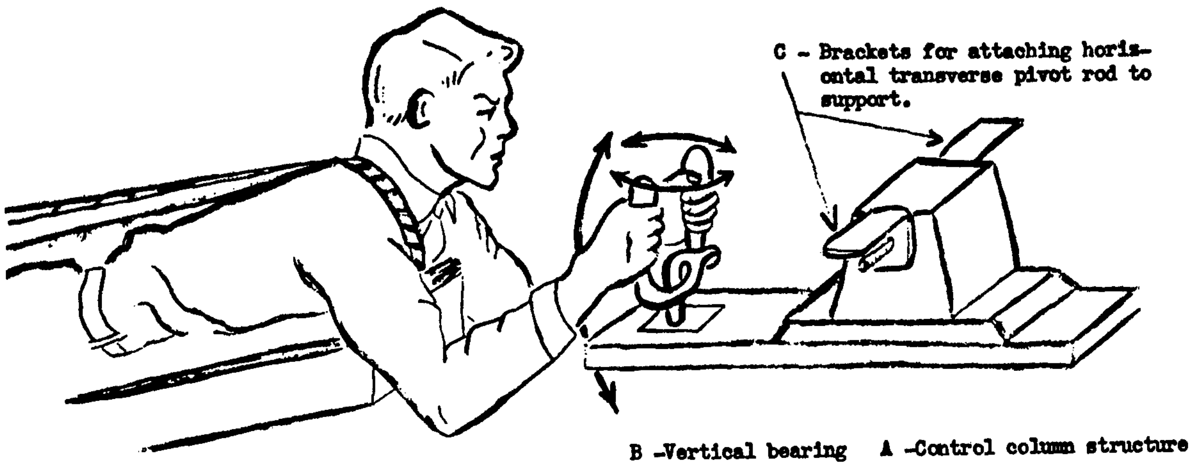


FIGURE 88 - 1

Illustration of Control Column for Measuring Rectilinear Up-Down and Reciprocal Forward-Backward Movements (some of the structural supports have been omitted to simplify identification).

TABLE 88 - 1

Descriptive Characteristics of the Sample and Comparisons with Available Aviation Cadet Data

	Cadets			Subjects			
	N	Median	Standard Deviation*	N	Mean	Standard Deviation	Percentile rank Of subjects' mean in cadet distribution
Height (inches)	2961	69.2	2.4	37	71.1	2.0	75th
Weight (pounds)	2960	153.1	17.3	37	162.1	17.2	70th
Arm Length** (inches)				37	24.9	1.3	
Age (year)	1454	Mean 23.3		37	24.3	2.5	

* Standard Deviation for cadets estimated from available percentile distributions by the formula: S.D. equals 1.4826 times one half the interquartile range.

** The measure of arm length is described in the text.

Pilot Experience

Hours	0	1-49	50-99	100-499	500-999	1000-1499	1500-1999	2000 plus
N	2	5	1	11	2	6	4	4

Handedness of Subjects	N
Right handed	36
Left handed	1

TABLE 88 - 2

Maximum Strength Statistics, Expressed in Pounds, for Each of Four Movements in Each of Nine Positions. N = 37

Bed Position Vertical Horizontal	Low Forward	Low Middle	Low Rear	Middle Forward	Middle Middle	Middle Rear	High Forward	High Middle	High Rear
				Down Movement					
Mean	174	155	132	133	137	124	143	151	88.6
Median	176	155	136	129	132	126	139	156	91.2
St. Dev.	30.6	27.5	29.6	28.4	28.4	29.1	35.7	39.2	28.2
Range	148	125	148	132	132	109	175	152	129
				Up Movement					
Mean	98.7	83.6	75.4	124	115	103	153	144	129
Median	96.7	81.0	72.4	123	112	103	151	146	130
St. Dev.	21.0	16.2	12.2	16.9	18.1	17.9	21.7	20.2	21.5
Range	116	74	51	82	85	71	110	96	90
				Rotate Left Movement					
Mean	186	222	299	221	258	336	234	286	298
Median	175	206	284	213	261	324	233	283	293
St. Dev.	41.8	63.5	69.2	41.8	60.0	61.5	40.9	46.4	57.8
Range	272	306	278	193	306	261	181	176	306
				Rotate Right Movement					
Mean	176	232	309	226	282	347	244	297	309
Median	176	218	296	221	268	336	238	290	304
St. Dev.	32.7	64.0	73.8	39.0	67.1	67.7	51.7	54.8	40.7
Range	130	317	317	151	283	272	261	221	340

TABLE 88 - 3

Reliability Coefficients of Maximum Strength Response for Each of Four Movements. N = 37

Movement	Position	r
Up	MM	.47
Down	MM	.72
Rotate right	MM	.80
Rotate left	MM	.80

TABLE 88 - 4

Statistics for Reasonable Strength Response in Middle-Middle Position for Each of Four Movements and Comparison of Mean Forces of Reasonable and Maximum Strength Conditions. N = 37

Movement	Mean	Standard Deviation	Ratio of Reasonable to Maximum Mean-Forces
Up	74.4	22.3	.66
Down	64.0	33.7	.49
Rotate right	131.0	60.7	.49
Rotate left	124.0	57.8	.51

TABLE 88 - 5

Mean Applied Force in Pounds for Maximum Response in Each Position for Each Movement. N = 37

Movement	Low Forward	Low Middle	Low Rear	Middle Forward	Middle Middle	Middle Rear	High Forward	High Middle	High Rear
Up	98.7	83.6	75.4	124.	115.	103.	153.	144.	129.
Down	174.	155.	132.	133.	137.	124.	143.	151.	88.6
Rotate right	176.	232.	309.	226.	282.	347.	244.	297.	309.
Rotate left	186.	222.	299.	221.	258.	336.	234.	286.	298.

TABLE 88 - 6

The Relative Efficiency of Each Movement in Each Position for Maximum Strength Response. N = 37 (The mean strength for each movement is taken as one hundred percent.)

Movement	Low Forward	Low Middle	Low Rear	Middle Forward	Middle Middle	Middle Rear	High Forward	High Middle	High Rear
Up	97	73	66	109	100	90	134	126	113
Down	127	113	96	97	99	90	104	110	64
Rotate right	66	86	115	84	105	129	91	110	115
Rotate left	71	85	115	85	99	129	90	110	114

TABLE 88 - 7

Mean Applied Force in Pounds of Maximum Strength Response for Three Vertical Positions of Each Movement. N = 37 (Each vertical position is an average of that position for the three horizontal distances.)

Vertical Position	Up	Down	Rotate Right	Rotate Left
High	142	128	283	273
Middle	114	131	285	272
Low	86	154	239	236

TABLE 88 - 8

Mean Applied Force in Pounds of Maximum Strength Response for Three Horizontal Positions of Each Movement. N = 37 (Each horizontal position is an average of that position for the three vertical levels.)

Horizontal Position	Up	Down	Rotate Right	Rotate Left
Forward	125	150	215	214
Middle	114	148	270	255
Rear	102	115	322	311

"Leg extension was constrained by requiring the subjects to kneel with the sole of the foot against a pressure plate and the knee touching a vertical block placed just ahead of it. This arrangement permitted full extension of the foot about the ankle joint while eliminating any effective leg action. The padded kneeling support extended almost to the ankle and was provided with a special pad for the lower part of the shin. A schematic representation of this arrangement is presented in Figure 89 - 1.

"The pressure plate was contrived to pivot about an axis approximating that of the ankle joint, and to deliver the pressure to the plate of a set of bathroom scales. Individual differences in distance between the pivot of the ankle joint and the sole of the foot was corrected for by the use of thin wooden spacers inserted between the pressure plate and the foot. Thus for all subjects the lower leg could be kept horizontal with the pivot of the pressure plate in the approximate axis of the ankle pivot. It should be noted that the apparatus is such as to make the determinations substantially isometric, i.e., the pressure plate moved very little under the pressure of the foot.

"Twenty-seven male students of the University of California served as experimental subjects.

"Twenty-five of the subjects had had some pilot experience; two had had none. Table 89 - 1 contains the information concerning the physical characteristics of the subjects as compared with aviation cadet norms from AAF Technical Report 5501, together with the information concerning the pilot experience of the subjects.

"For each subject, one measure of strength was obtained for each foot in each of the five positions of foot extension (see Figure 89 - 2). ...It was thought that the one-hour period which separated the two determinations on the same foot was sufficient to eliminate the effects of fatigue induced by the first determination. Thus four determinations were made in each experimental hour, and the twenty determinations made on each subject were distributed over three experimental hours separated by from one to three days.

"Right and left foot determinations were counterbalanced so that each foot was tested first half of the time. The sequence of the positions utilized (i.e., the five degrees of foot-extension employed) was determined by the use of random numbers. A different random sequence was used for each subject.

"All subjects wore their shoes during the test. The effects of variations in the thickness of the soles were eliminated by the use of spacers... . It should be noted, however, that the heel of the shoe effects an alteration in the angle made by foot and lower leg, so that the actual angles against which the subjects worked were not quite those cited. The heel of the ordinary shoe provides a lift which for the average foot increases this angle by three to five degrees, and this value should be subtracted from the experimental angles cited in the text if actual angle is desired.

"It must be emphasized that no significance attaches to the absolute values in pounds reported here, since they are in large part a function of the arbitrary choice of 22.5 inches as one arm of the recording lever. Design engineers must reduce these values to such form as they may require.

"In order to determine the extent to which stable differences existed among pilots with respect to the forces which could be applied in this situation, correlations were run between single determinations of right- and left-ankle performance for each of the five angular positions of the foot. Reliabilities so obtained would not be expected to be as large as though correlations had been run between two separate determinations on the same foot, but they do serve to indicate that such stable individual differences are present and to suggest the order of magnitude of the reliability coefficients. It will be noted that the reliability is lower at the extreme positions of the foot. This is a finding which is to be expected in view of the reports of the subjects that the 70° position is often painful and that it was difficult to flex the ankle so as to place the foot in the 110° position.

"It is of interest to note that throughout the range of angular positions investigated the mean values for left and right foot are virtually identical.

"Attention must be called to the reports of discomfort in both extreme positions, as well as the objective evidence of the unsatisfactory nature of these positions in the low reliabilities cited above. On the basis of the quantitative data as well as of reports from subjects, it would appear that if controls were to be operated by such foot extension and flexion as used in this study the practical limits through which the foot may be expected to function satisfactorily are between about 85° and 105°.

"Although we have no data on the subject, it would appear that in a reciprocating type of control, the decrease in effectiveness of extension might well be accompanied by increase in effectiveness of flexion of the opposite foot so that over the range 85° - 105° the maximum forces applicable through such reciprocating mechanism might remain reasonably constant."

The report is 10 pages long and includes 3 tables and 4 figures. Tables 89 - 1 and 89 - 2 are included in this annotation. There is no bibliography.

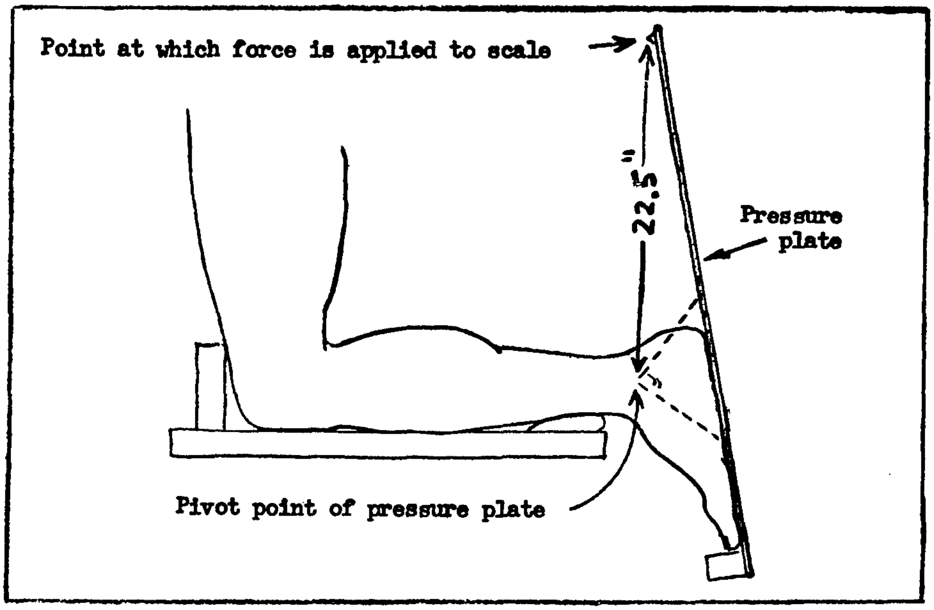


FIGURE 89 - 1

Schematic Diagram of Apparatus Showing
Placement of Leg and Foot

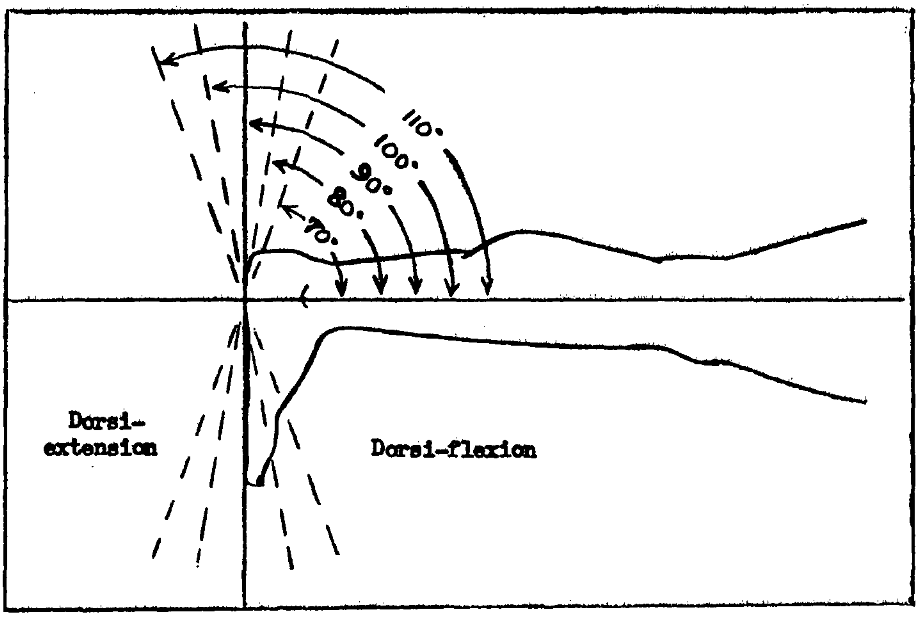


FIGURE 89 - 2

Five Positions of Foot

TABLE 89 - 1

Descriptive Characteristics of the Sample and Comparisons With Available Cadet Data

	Aviation Cadet Norms			Present Subjects				Percentile Ranks of Subjects' Median On Cadet Norms
	N	Median	Standard Deviation*	N	Median	Mean	Standard Deviation	
Height (inches)	2961	69.2	2.4	27	71.5	71.1	2.2	83
Weight (pounds)	2960	153.0	17.3	27	161	162.3	17.3	67
Foot Length (inches)	2959	10.5	0.44	23	10.6	10.5	0.60	58
		Mean						
Age (years)	1454	23.3		27	23.5	24.4	2.75	

* The Standard Deviation for cadets was estimated from available percentile distributions by the formula: $S.D. = 1.48 \times \frac{Q3-Q1}{2}$

Pilot Experience

Hours	0	1-49	40-99	100-499	500-999	1000-1499	1500-1999	2000-up
N	2	6	0	8	1	4	2	4

TABLE 89 - 2

Means, Standard Deviations, Reliability Coefficients, and Coefficients of Variation for the Right and Left Foot in All Positions, and Correlations Between Height, Weight, and Ankle-Strength.

Foot Angle	70° R	70° L	80° R	80° L	90° R	90° L	100° R	100° L	110° R	110° L
Means (pounds)	23.6	23.7	41.2	38.4	52.0	50.3	60.9	61.3	71.7	71.2
Standard Deviation (pounds)	7.50	7.16	11.5	11.1	12.7	12.3	17.8	17.1	16.1	17.9
Coefficients of Variation	32	30	28	29	24	24	29	28	22	25
Reliability Coefficients	0.54		0.71		0.73		0.71		0.44	
Correlations height with strength	0.39		0.48		0.50		0.38		0.38	
Correlations weight with strength	0.32		0.46		0.57		0.47		0.54	

90. Brown, C.W., E.E. Ghiselli, R.F. Jarrett, E.W. Minium, R.M. U'Ren. (University of California). Comparison of Aircraft Controls for Prone and Seated Position in Three-Dimensional Pursuit Task. AF Technical Report No. 5956, United States Air Force, Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio, March 1950. (Armed Services Technical Information Agency No. ATI-73414.)

"Previous studies from this project have indicated that it is possible for prone pilots to apply to control devices forces adequate for the control of aircraft. Of importance among the problem of prone flight is that of the efficiency with which the craft may be controlled in the prone position as compared with the efficiency of its control from other pilot positions." ..."The present study therefore has undertaken a comparison of the effectiveness of performance with three-dimensional hand controls in the prone and seated position and a comparison of the relative effectiveness of the seated-conventional-controls and the prone-three-dimensional-hand-controls. We have asked the following four questions: (1) Is the California*three-dimensional hand control inferior to the conventional control device (stick and rudder) when both are used by the seated pilot? (2) Is the California three-dimensional hand control operated by the prone pilot inferior to the conventional control operated by the seated pilot? (3) Is the Amtmann ** three-dimensional controls operated by the prone pilot inferior to the conventional control operated by the seated pilot? (4) Is there evidence for the superiority of either the California or Amtmann three-dimensional controls when both are operated from the prone position?

"In the present study the apparatus consists of a target (a model airplane) which can be displaced in three dimensions by an irregular cam, control devices and linkages to permit the subject to compensate for the cam-actuated displacements of the target, and clocks to record total time and time on target in each of the three dimensions and in all three dimensions.

*Designation used for a modified experimental control furnished by the Aero Medical Laboratory, Wright-Patterson Air Force Base.
**This control manufactured by Tison Brothers Mfg. Co. for the Air Materiel Command.

"The target is a model of a P-39 having a wing span of 17 inches and length of 16 3/8 inches mounted so it may be displaced about each of the plane's three axes. The target, the displacing mechanism, the conventional seated controls (stick and rudder) and a scoring clock together comprise the SAM Airplane Control Test Unit Model B. The target was located so that horizontal stabilizer of the plane was at eye level. The target was finished in black enamel; the control mechanism was covered with black, non-reflecting cloth.

"The subject's task was to compensate - by manipulation of the controls - for the cam-actuated displacements of the target; he was required to keep the plane straight and level. When he was 'on target' - i.e., within scoring tolerances in all three dimensions - a small red pilot light in front of the subject lighted up. The micro-switches which actuated the scoring clocks were located close enough to the subject that if he were attentive he could hear them click above the sound of the motor which drove the cam. The control panel for the apparatus together with the scoring clocks were located in an adjoining room from which communication with the subject could be carried out in normal tone of voice through a communicating door which was left ajar.

"The scoring tolerances for the three dimensions in which the target might be displaced were measured at the target itself, 1.9° about the lateral axis (elevators), 4.1° about the vertical axis (rudder), and 3.4° about the longitudinal axis. These scoring tolerances were as small as they could be made without very extensive modifications of the SAM* apparatus. The micro-switches which activated the timer clutches did not break sharply; consequently these scoring tolerances were slightly larger if the displacement out of the scoring area was very gradual.

"The conventional seated controls used were those provided as part of the SAM* Airplane Control Test Unit."

For the California three-dimensional controls, "a half-wheel about ten inches, in diameter provided the hand grip. This wheel rotated about a horizontal axis parallel with the fore-aft axis of the cockpit and was linked to 'aileron control'. The shaft upon which this wheel rotated was also permitted fore-aft motion, and this motion was linked to 'elevator control'. It was possible, by bringing the cables for these two movements almost exactly through the third (vertical) axis to provide for three independent movements. The third movement involved 'right-left' displacement of the controls and was linked to 'rudder control'. For this rudder control a given angular displacement always had the same effect on the plane, but the linear displacement necessary for a given effect varied, of course, with the elevator position. The vertical axis of the controls was 6 1/4 inches forward of the foremost position of the 'elevator controls'.

"In the case of the Amtmann three-dimensional controls the two hand grips are at the forward end of a pair of fore-arm rests. They move reciprocally vertically about pivot points below the elbow rest. They are linked so as to move mutually from side to side about pivots located at the same points, and the entire column, arm rests included, may be moved linearly fore and aft. In the present study the vertical movement was linked to 'aileron control', the lateral movement to 'rudder', and the longitudinal to 'elevator'. The total extent of movement for the aileron movement was 7 3/8 inches, the scoring tolerance for this movement being 0.62 inches. The corresponding values for rudder movement were 7.0 inches and 0.64 inches; for elevator movement the values were 8.0 and 0.23.

"For use with the California three-dimensional controls, the prone bed was a modification of the support recommended by earlier workers. The support for the lower part of the body was padded and was elevated 7° from the horizontal. The chest support was made of sponge rubber over webbing and made an angle of 18° with the lower part of the bed; it was 12 inches wide at the forward end, widening out toward the rear. A padded headgear (Clark, W.G., Henry, J.P. Studies on Lying in the Prone Position) counterbalanced with a five-pound weight was provided to moderate the fatigue attendant upon continued support of the head in the awkward position demanded by the prone position.

* School of Aviation Medicine

"The design of the Amtmann three-dimensional controls made it necessary to permit only a 5 1/2° angle to the support for the lower part of the body. Thus the chest support made an angle of 20° with the lower body support. The chest support for use with these controls had to be narrower and could not widen out toward the rear, since to do so would involve a restriction of the control movement.

"Each experimental session involved seven runs of four minutes each...thus requiring the subject to remain in the apparatus about 37 minutes. After each four-minute run, on-target times were recorded from five clocks (total time, on-target in each of the three dimensions, on-target in all three dimensions).

"Four experimental groups were run as follows:

Pursuit Task I	-	Conventional controls operated from the seated position
Pursuit Task II	-	California three-dimensional hand controls operated from the seated position
Pursuit Task III	-	California three-dimensional hand controls operated from the prone position
Pursuit Task IV	-	Amtmann three-dimensional hand controls operated from the prone position

"One hundred and eleven male students at the University of California served as subjects, twenty-seven each on Tasks I, II, and IV, and thirty on Task III.

"The results indicated that for either of the positions, seated or prone, the type of control utilized made little or no difference as far as performance on the pursuit task was concerned. However, performance in the prone position was found to be significantly inferior to that in the seated position. The indications are, therefore, that for this kind of task the type of control is relatively unimportant but the position of the pilot's body may be a prime consideration."

The report is 18 pages long and includes 6 tables and 3 figures. A six-item bibliography is included.

See also: Brown, C.W. et al. Magnitude of Forces Which May be Applied by the Prone Pilot to Aircraft Control Devices. 1. Three-Dimensional Hand Controls. Report No. 3, Engineering Division, Air Materiel Command, Memo. Rept. No. MCREXD-694-4J, Air Materiel Command, USAF, January 1949.

Brown, C.W. et al. Magnitude of Forces Which May be Applied by the Prone Pilot to Aircraft Control Devices. 2. Two-Dimensional Hand Controls. Air Force Technical Rept No. 5954 Engineering Division, Air Materiel Command, USAF, February 1950.

Brown, C.W. et al. Magnitude of Forces Which May be Applied by the Prone Pilot to Aircraft Control Devices. 3. Foot Controls. Air Force Technical Rept No. 5955, Engineering Division, Air Materiel Command, USAF, February 1950.

Additional reference: Clark, W.G., Henry, J.P. Studies on Lying in the Prone Position. Aero Medical Laboratory, University of Southern California, National Research Council Committee on Medical Research #466, August 20, 1954.

91. Canfield, A.A., A.L. Comrey and R.C. Wilson. An Investigation of the Maximum Forces Which Can be Exerted on Aircraft Elevator and Aileron Controls. (Research Report No. 3, Psychology Department, University of Southern California.) (Contract No. N6 ori 77, Task Order 3) Office of Naval Research, Washington, D.C., September 1948 (Armed Services Technical Information Agency No. 52493).

Review of the Literature and Background of the Problem

"In a study of the effects of negative acceleration under flying conditions, pilot subjects reported that the discomfort experienced was equal to or less than that experienced on the centrifuge (Maher, P.J. Human Tolerance to Negative G in Aircraft).

"In an early study with two subjects, Gough and Beard (Gough, M.N., and Beard, A.P. Limitations of the Pilot in Applying Forces to Airplane Controls) studied the maximum forces which could be exerted on controls under varying conditions. They found that pilots could pull harder on elevator controls than they could push except when the stick was well pack. The subjects could pull less on the aileron controls than they could push, with both forces decreasing with the deflection of the stick from the center position. The maximum aileron forces measured were about 90 lbs. and the maximum elevator forces were 200 lbs.

"Hertel (Hertel, H. Determination of the Maximum Control Forces and Attainable Quickness in the Operation of Airplane Controls) found that push and pull forces on the elevator controls with both hands were equal, about 275 lbs. for a strong pilot. The aileron forces were 73 lbs. for two-hand operation, 60 lbs. for one-hand push, and 44 lbs. for one-hand pull. The arrangement of the pilot seat and controls was described only as 'like the usual one on airplanes' so the results for the elevator forces are not too meaningful, since Gough and Beard (Gough, M.N., and Beard, A.P. Limitations of the Pilot in Applying Forces to Airplane Controls) found that the force which can be exerted depends to some extent upon the distance of the stick from the back of the seat.

"In a study using wheel-type controls, McAvoy (McAvoy, William H. Maximum Forces Applied by Pilots to Wheel-type Controls) found that pilots secured with safety belts, with the stick 24 inches from the back of the seat, exerted forces which varied with the size of the wheel and the distance of the wheel above the seat.

"In a previous report from this laboratory (Lombard, Charles F. and others. The Influence of Positive (Head to Foot) Centrifugal Force upon a Subject's (Pilot's) Ability to Exert Maximum Pull on an Aircraft Control Stick), it was stated that the mean maximum pull increased slightly from one to two G, decreasing thereafter with increased G up to and including five G. Variation in arm position, measured by the angles of the members in relation to the direction of the G forces did not significantly influence maximum pull at four G, within the limits of the arm angles used.

"In order to determine the maximum forces which could be exerted in other directions, a series of experiments was begun in which subjects were instructed to exert maximum forces with both hands on the stick in forward, left, and right directions while radial acceleration was increased from one to five G. The results of these experiments will be reported in this paper.

Apparatus

"The series of experiments reported here was carried out under different conditions of radial acceleration produced on the human centrifuge at the University of Southern California. The subject was seated in a simulated cockpit which had been set up in the centrifuge cab. Navy Coverall, Type Z-2, anti-blackout suits were worn by the subjects and safety belts held them securely in position. The suits were pressurized by 0.9 to 1.5 lbs. per square inch for each G attained. Pressure was delivered through a Navy C-C-1 adjustable valve to the suit beginning at a point between 1.5 and 2.3 G.

"The pilot seat was set at 9 inches above the cab floor. An isometric control stick was located 24 inches forward of the back of the seat. The stick was designed to yield deflections of approximately 3/4 inches at the maximum loads expected during the experiments. Deflections of the stick corresponding to operation of elevator controls in the fore-and-aft direction were recorded separately from deflections in the lateral direction for aileron controls. Deflections were measured by strain gage bridge circuits connected to Heiland-type A galvanometers." The apparatus could determine maximum pull forces of subjects within an error of 2 lbs.

Experimental Design

"This series of experiments was designed to yield information concerning the maximum force males can exert (a) in the forward direction, (b) laterally to the left, and (c) laterally to the right on an isometric control stick. In addition, relationships between maximum forces as well as hypotheses to account for the findings were sought.

"In all conditions, forces were exerted with both hands while the subject's feet were resting on the floor of the cab. Prior to experimental trials, all subjects were given rigorous physical examinations to ensure that they were in good physical condition. Each subject was also given two trial series of indoctrination runs. On one day, he rode the centrifuge at two and three G and on the second day, at three, four, and five G. If no ill effects were noted, the subject was used for the experimental trials. Both pilots and non-pilots were used in the experiments." The authors do not specify the relative proportion of each.

"The procedure with each subject was as follows. He was first secured in the pilot seat, then, instructions were read as follows:

> In this experiment, we want to determine how much force you can apply to this control stick. Grasp the stick with both your hands and push it (right, left, or forward) as hard as you can. Relax, and then immediately push again. At the completion of your second maximum push, drop your hands into your lap. The centrifuge will then be stopped. Do not push on the stick until the observer tells you to do so. Keep your feet resting on the floor of the cab. Remember, push once as hard as you can, relax, push again, and then drop your hands. Do you understand?

"According to a predetermined randomized order, each subject was given five runs on the human centrifuge at five different G-levels, one through five. Two minutes elapsed between each run. On attaining the desired G-level, the experimenter riding the center position on the centrifuge called to the subject to push on the stick. The subject pushed on the stick with his maximum strength, relaxed, and then pushed again, after which he let his arms drop, indicating that he had finished the task. The centrifuge was then stopped.

"For each subject, four different series of runs were given, each on a different day. This total procedure was carried out completely for each of three movements, right, left, and forward push. Eleven subjects were used for the right push, ten for the left push, and nine for the forward push.

"In order to avoid errors due to positioning effects with a fixed order of G runs, a counterbalanced order of G trials was established for each of the three experiments.

"The experiments were designed so that for any one of the three experiments a given number of subjects performed a specified task on four separate occasions and under five different experimental conditions. The task was performed four times to give stability to the figures obtained. The five different conditions constituted the experimental variables."

"For each of the three experiments, the average force exerted at each G-level was compared with the average force exerted at every other G-level..." The authors corrected the standard error of the difference between means so as to allow for the correlation between the stick-forces exerted by the same subjects under the different G conditions. The statistical significance of the mean difference was evaluated by t.

"The formula used for computing the degrees of freedom in these experiments was:

$$\text{degrees of freedom} = N(k - 1) - 1$$

N is the number of subjects participating, and k is the number of trials by each subject. This value of k was eight, in every case, because each subject exerted his maximum force twice in each run and had four runs at each G-level. It should be emphasized that this formula for the number of degrees of freedom applied only in the situation where we are determining the significance of the difference for the particular group of subjects involved. If we were attempting to predict that these differences represent the entire population of individuals of which our sample is presumably a random selection, then the degrees of freedom would equal N - 1. This would make the size of the t-ratio much smaller and hence of less significance. In order to obtain t-ratios for population prediction, large numbers of subjects would be required. ...If the functions measured here are based upon stable physiological functions, differences discovered for a group of normal, healthy males should hold for the larger population of flying personnel."

Results

Tables 91 - 1, 91 - 3, and 91 - 5 give the mean force in pounds exerted in the forward, right, and left push conditions respectively at each level of G. Tables 91 - 2, 91 - 4, and 91 - 6 give the t-values for those comparisons which were significant at the 5% level or beyond. Asterisks indicate non-significance.

TABLE 91 - 1

Forward Push (N = 9)

G-level	Mean	Standard Deviation	$S.E._m$
1	183.6	32.3	3.8
2	185.0	31.2	3.7
3	187.2	33.1	3.9
4	186.1	27.4	3.2
5	183.1	32.8	3.9

TABLE 91 - 2*

Forward Push t-ratios

G-level	2	3	4	5
1	*	*	*	*
2		*	*	*
3			*	3.0
4				2.2

* Denotes a t-ratio less than that required for significance.

TABLE 91 - 3

Right Push (N = 11)

G-level	Mean	Standard Deviation	$S.E._m$
1	72.1	10.1	1.1
2	75.8	9.7	1.0
3	78.3	7.7	.8
4	80.0	7.4	.8
5	80.8	8.7	.9

TABLE 91 - 4

Righ Push t-ratios

G-level	2	3	4	5
1	8.7	13.6	7.7	9.3
2		2.7	4.2	4.4
3			2.8	3.1
4				2.1

TABLE 91 - 5

Left Push (N = 10)

G-level	Mean	Standard Deviation	S.E.$_m$
1	65.2	12.2	1.4
2	67.6	12.8	1.4
3	71.2	14.2	1.6
4	71.0	13.9	1.6
5	73.4	12.7	1.4

TABLE 91 - 6*

Left Push t-ratios

G-level	2	3	4	5
1	5.4	10.0	7.5	11.1
2		9.9	5.4	9.8
3			*	5.2
4				27.0

*** Denotes a t-ratio less than that required for significance.**

"A previous report from this laboratory (Lombard, Charles F. and others. <u>The Influence of Positive (Head to Foot) Centrifugal Force upon a Subject's (Pilot's) Ability to Exert Maximum Pull on an Aircraft Control Stick</u>) reported the results of a study to determine the maximum forces which could be exerted on a control stick by pulling showed a gradual change in the mean force with increased G. The applied force rose slightly between one and two G, declined between two and three G to about the same level as one G, and declined further thereafter. This study showed a definite decline between three and five G in the maximum force exerted which is substantially what occurred in the first part of the present experiment with maximum push on the control stick in the forward direction. This trend was not found when the forces were exerted in the lateral directions, however. In these cases, it was found that the maximum forces exerted steadily increased with G.

Discussion

"The apparent reversal of forces applied with increasing radial acceleration represents an unexpected result. The rather consistent decline of force application in the aft direction under G as compared with the consistent increase for forces applied in the two lateral directions does not seem accountable in the light of any existing hypothesis.

"Inasmuch as an isometric stick was used in the experiments, any theories as to the effective weight of the arm in a changed position with respect to the application of forces must be discounted because the position of the arm in relation to the direction of the application of force was unchanged.

"The possibility of experimental error must be considered, in view of the apparent contradiction of expected and obtained results.

Conclusions

"The results of the forces applied under normal one G and under increased G conditions indicate that greater forces can be applied in the fore-and-aft directions than in the lateral directions with an aircraft control stick. Further, it is indicated that pull forces are somewhat larger than push forces. The changes in force application with increased G, under antiblackout suit protection, are not consistent from one direction of force application to another. The changes in the force applied are, however, relatively small and do not seem to indicate any modifications or changes in the stress design and limits of the controls now in use."

This report is 16 pages long and contains 13 tables. A list of six bibliographic references is included.

92. Cochran, Leroy B. Studies on the Ease with Which Pilots Can Grasp and Pull Ejection Seat Face Curtain Handles. Journal of Aviation Medicine, Volume 24, No. 1, February 1953, pp. 23-28.

"This paper reports the results of tests designed to investigate pilot ability to actuate the Martin-Baker type ejection seat. ...Some pilots have reported that they have encountered difficulty in raising their arms to grasp the handles of the face curtain of the Martin-Baker type ejection seat. These difficulties have occurred during emergency escape when the motion of the plane was subjecting the pilot to positive radial acceleration."

"Thirty naval fighter pilots, of various anthropometrical measurements,...were tested on the Pensacola Human Centrifuge in their ability to actuate the Martin-Baker ejection seat mechanism. For these tests the subjects, protected by antiblackout suits, were subjected to levels of position radial acceleration about 2.0 g above their relaxed blackout tolerance.

"The task of the pilot essentially consists of raising the hands to a point above and behind the head, grasping the face curtain handles and drawing the curtain down across the face."

"The results suggest that, unless extremely fatigued, most suit-protected pilots should be able to perform the arm movements necessary to actuate the Martin-Baker ejection seat at 2.0 g above their control blackout level if the g were a constant one. There were no means available by which their ability could be tested under conditions of fluctuating g-levels.

"A marked degree of success would appear to depend on the pilot's preknowledge of the effects of such forces on him and his plane, and proper instruction as to procedure and techniques employed which facilitate his ability to actuate the ejection seat under high accelerative forces."

No data are presented as to the muscular forces which the subjects were required to exert, although for each subject data are given on age, height, weight, actuation time and the various g-levels. "The first few subjects pointed out to their successors that at one point in the effort, with arms about half elevated, an apparent point of failure would be reached, but with persistence, this point would be suddenly passed and the pilot would find his hands on the face curtain handles with subsequent successful actuation of the ejection seat. ...It was observed that under high g-levels the subject is unable to elevate the arms above the head if fully extended." However, this was possible with the elbows held firmly in place against the body and the hands close to chest and face.

A series of seven photographs illustrates the task required of the subjects. In addition to the photographs the article includes the table of subject data, but no bibliographic references.

93. Darcus, H.D. and Nancy Salter. The Amplitude of Pronation and Supination with the Elbow Flexed to a Right Angle. Journal of Anatomy (Great Britain), Volume 87, Part 2, April 1953, pp. 169-184.

The available literature on the measurement of the amplitude of pronation and supination is reviewed.

A wrist-cuff arthrometer, which has been designed to measure the amplitude of radio-ulnar movement at the distal end of the radius, is described.

Measurements of the amplitude of pronation and supination with the elbow flexed to 90° have been recorded with a hand-grip arthrometer (twenty-four subjects), the wrist-cuff arthrometer (eleven subjects) and Patrick's goniometer (seven subjects). In the majority of cases, both right and left sides have been studied. Generally accepted definitions of the terms pronation and supination are that, with the forearm horizontal, pronation is the movement which turns the palm of the hand to face downwards and supination that which turns the palm to face upwards.

TABLE 93 - 1

Summary of Average Amplitudes of Pronation and Supination as Measured from (A) the Hand-grip Arthrometer, (B) Patrick's goniometer and (C) the wrist-cuff arthrometer.

Experiment	Number of subjects	Total number of readings	Amplitude (°) Right		Left
A 1	13	650	165.7		168.8
2	4	200	181.5		184.0
3	2	20	173.8		175.3
4	5	100	187.0		—
			Mean	173.8	
B 3	2	20	166.7		168.1
4	5	100	167.7		—
			Mean	166.9	
C 2	4	200	154.4		158.0
3	2	20	152.9		155.3
4	5	150	147.9		—
			Mean	156.3	

The mean amplitudes obtained have been summarized in Table 93 - 1. The largest readings were obtained with the hand-grip (protractor type) arthrometer which, besides recording rotation of the radio-ulnar joints, also measures supplementary movements of the hand and wrist. Intermediate values were recorded with a pendulum-type arthrometer, which excluded hand movements but allowed rotation at the intercarpal joints. The lowest readings were recorded using the wrist-cuff arthrometer, which measures almost exclusively movements about the radio-ulnar joints.

No significant association between amplitude and age, sex or previous injury was found in the subjects studied.

Although differences were found between the amplitudes measured on the right and left sides of the same individual, these usually did not reach a significant level.

Wide variation occurred between readings taken successively on the same day and from day to day. Possible reasons for these variations are discussed.

The results of the present experiments are compared with those of Glanville and Kreezer (Glanville, A.D., and Kreezer, G. The Maximum Amplitude and Velocity of Joint Movements in Normal Male Human Adults) in Table 93 - 2, and the methods of measuring and recording the amplitudes of pronation and supination are discussed.

TABLE 93 - 2

(A) Mean Amplitude of Pronation and of Supination as Measured from the Hand-grip Arthrometer. Neutral Point with the Handle Vertical (0°). (B) The Figures of Glanville and Kreezer (Glanville, A. D., and Kreezer, G. The Maximum Amplitude and Velocity of Joint Movements in Normal Male Human Adults) obtained with a Pendulum Goniometer are Included for Comparison.

	No. of subjects	Total no. of observations	Right Amplitude (°)	Right Range	Right S.D.	Left Amplitude (°)	Left Range	Left S.D.
					Pronation			
A	13	650	63	49-84	10.5	62	49-75	8.6
B	10	30	91	59-139	25.8	93	69-135	20.7
					Supination			
A	13	650	102	86-122	11.1	106	90-121	10.0
B	10	30	99	81-114	11.0	101	74-114	10.8

It is concluded that, owing to the wide individual variation, "normal" figures for the amplitude of pronation and supination are only of limited value. In clinical work, the findings of these experiments indicate that, in cases of injury to one limb, readings from the opposite side are a more reliable yardstick.

A bibliography of 30 items is included.

94. Darcus, H.D. A Strain-Gauge Dynamometer for Measuring the Strength of Muscle Contraction and for Re-educating Muscles. Annals of Physical Medicine, Volume 1, No. 5, January 1953, pages 163-176.

"A strain-gauge dynamometer has been constructed for the accurate objective measurement of muscle strength.

"The underlying principle is that the muscle force developed during voluntary contraction is resisted by a spring-steel bar which bends in proportion to the torque applied. This deformation is measured by the change in electrical resistance of two strain-gauge elements attached to the steel bar.

"By adjustments to the apparatus, torques developing in different positions of the joint can be determined.

"The apparatus can also be used for muscle training; it appears to have particular application to the training of muscles too weak to produce limb movement."

The article is 13 pages long, containing one table, five figures, one photograph, and 10 bibliographic references. The table is reproduced and included in this annotation.

95. Evans, F.G. (Wayne University). Methods of Studying the Biomechanical Significance of Bone Form. American Journal of Physical Anthropology, Volume 11, No. 3, September 1953, pp. 413-428.

"Many of the techniques employed by engineers for stress-strain analysis in engineering structures and materials are also applicable for studying similar phenomena in bones. By these means one may study the stresses and strains produced in bones under controlled conditions of loading and orientation in which the magnitude of the load or the energy applied to the bone, as well as its point of application and direction, can be controlled. It is thus possible to obtain some idea of the behavior of the bone as a mechanical structure or unit."

TABLE 94 - 1

Summary of Results of Training Experiments

Age and Sex	Physical Condition	Movement Trained	Joint Position	No. of Training Periods Weekly	Applied Muscle Force in Kg.-m. Average of 150 Readings: Consecutive Groups	Average of 10 Readings Before	Average of 10 Readings After	Percentage Increase A	Percentage Increase B
21 M.	Normal	Flexion of R. elbow	Flexed to 90°	5	6·31 7·17 7·32 7·69 8·20	5·90	8·41	42	33
20 M.	Normal	Flexion of R. elbow	Flexed to 90°	5	5·86 6·97 7·38 7·34 7·69	5·78	7·86	36	31
22 M.	Normal	Supination of R. hand	−60°*	5	1·74 1·88 1·88 1·85 1·91	1·66	1·97	18	7
21 M.	Normal	Pronation of R. hand	+60°*	5	0·99 1·13 1·27 1·22 1·26	0·90	1·31	46	33
		Pronation of L. hand		5	1·24 1·39 1·40 1·37 1·46	1·29	1·57	22	22
19 M.	Normal	Pronation of R. hand	+60°*	5	0·74 0·84 1·02 1·27 1·21	0·91	1·23	35	82
24 F.	Normal	Extension of R. knee	70° from full extension	3	10·66 11·12 13·35 12·56	10·63	12·28	16	—
		Extension of L. knee		3	10·28 11·48 11·64 11·66	9·41	12·08	27	—
†21 M.	Poliomyelitis 6 months before training	Extension of R. knee	70° from full extension	3	8·77 10·62 12·40 13·41 14·45 14·87 17·71 17·19 18·74 17·90	9·37	19·95	113	123
		Extension of L. knee		3	1·11 1·68 2·94 3·66 4·52 4·73 5·33 5·67 6·64 7·13	0·91	7·33	706	637
†22 M.	Operation for recurrent dislocation of shoulder 6 weeks before training	Abduction of L. shoulder	Arm abducted 15° from side of body	6	2·87 3·20 4·19 4·35 (Average of 10 readings on normal right side—5·69)	2·55	5·12	103	—

* Point of reference (0°) with thumb superior, palm facing medially when forearm horizontal. Plus values indicate angular displacement from this point towards full supination, and minus values towards full pronation.
† Experiment still in progress.

In analyzing the distribution of physical stresses in a material, a stress coat or powder is deposited over the surface in question. Under strain the coating will undergo changes in surface distribution, giving significant indication of the stresses taking place.

Another method used in physical testing for stress measurement is to utilize strain gages, the magnitude of the stress being indicated by variance in electrical resistance according to a known scale.

The article is 15 pages long. Two figures are included. A bibliography of 24 references is listed.

96. Fisher, M.B. and James E. Birren. Age and Strength. Journal of Applied Psychology, Volume 31, 1947, pages 490-497.

This article demonstrates the relation of some scores of hand strength to the age of the subjects tested, and makes some comparisons with earlier work concerning age and strength. "The dynamometer test procedure requires the subject to squeeze the hand dynamometer at three second intervals, beginning with a squeeze of 27 kg (18 kg for women) and increasing the force exerted each time by an increment of 3 kg until he is unable to achieve the required increase in level of performance. The score for one hand is the kilogram reading of the last try and the score for a test is usually taken as the mean score of the two hands. Calibrated Smedley hand dynamometers were used.

"Age and dynamometer data are available on six groups of subjects. ...The naval personnel were tested on both hands; the industrial groups, on the preferred hand only.

"Correlation coefficients between dynamometer score and age, height, and weight have been calculated separately for the six groups of subjects, and show some consistency. In the case of the correlation with age, the correlation ratio, eta, becomes a more valid measure of the relationship than r. There is a maximum in the curve for each sample when mean dynamometer score is plotted against age group and the distribution of ages with respect to this maximum can determine both the size and sign of the product-moment coefficient. Some significant differences among the r's in the first row of coefficients in Table 96 - 1 are to be explained on this basis.

"The data of the two groups of male industrial workers were combined for treatment by analysis of variance... . A significant relation was found between age and dynamometer score as shown in the following tabulation:

Source	Sum of Squares	d.f.	Variance
Between Age Groups	303.12	7	43.30
Within Age Groups	2723.23	544	5.01
Total	3026.35	551	

$F = 43.30/5.01 = 8.64$ (d.f. for $F = 7$ and 544)

With these degrees of freedom an F of 5.67 would be significant at the 1% level of confidence. The data of the two male naval samples were similarly combined and analyzed... . In this group, which had a more restricted age range than the industrial workers, the F-ratio was not quite significant at the 5% level. Eta's, computed on the same sets of combined data, were 0.30 for the industrial men, and 0.21 for the naval men, values which are, respectively, more than seven times and more than three times their standard errors."

From an analysis of other data "it is clear that the development of muscular strength follows a systematic trend with an increase in strength up to the late twenties and a decline, usually at an increasing rate, from that time on."

"1. Measurements of hand strength on a group of 552 male manual industrial workers showed maximum strength in the middle twenties with a continuous decline thereafter. At age 60 the decline in average strength amounted to 9.25 kg, or 16.5% from the maximum. There was considerable overlapping among age groups.

"2. These findings are in agreement with other data on several measures of muscular strength which show that strength increases up to the middle or late twenties and declines continuously thereafter. In most studies the rate of decline increases with age.

"3. Sources of error in 'cross-sectional' stúdies and the relation of strength to some other aspects of ageing are discussed."

This article is seven pages long, containing four tables, one figure, and a bibliography of 18 references. The main data of the report are included in this annotation.

TABLE 96 - 1

Coefficients of Correlation Between Dynamometer Score and Age, Height and Weight

Variable Correlated with Dynamometer Score	Naval Personnel			Industrial Workers		
	Reliability Group N = 72	Camp Lejeune Group N = 90	Waves N = 161	Plant 1 Men N = 313	Plant 2 Men N = 239	Plant 2 Women N = 98
Age (r)	.32	−.40	.00	−.16	−.38	−.20**
Age (cla)	.36	.24*	.21	.20	.42	.14**
Height (r)		.28	.22	.35	.25	.26
Weight (r)		.54	.50	.40	.34	.16**

All coefficients are significantly different from zero ($P < 1\%$) except .00 and: *, P = 2-5%; **, $P > 5\%$.

TABLE 96 - 2

Dynamometer Score and Age in 552 Male Manual Workers in Industry

Age	18-22	23-27	28-32	33-37	38-42	43-47	48-52	53-68
N	28	82	153	126	72	42	29	20
Mean score (kg.)	53.46	56.05	54.23	53.33	52.42	50.36	48.31	46.80
σ	5.80	6.93	6.63	6.96	6.15	7.18	6.52	5.88

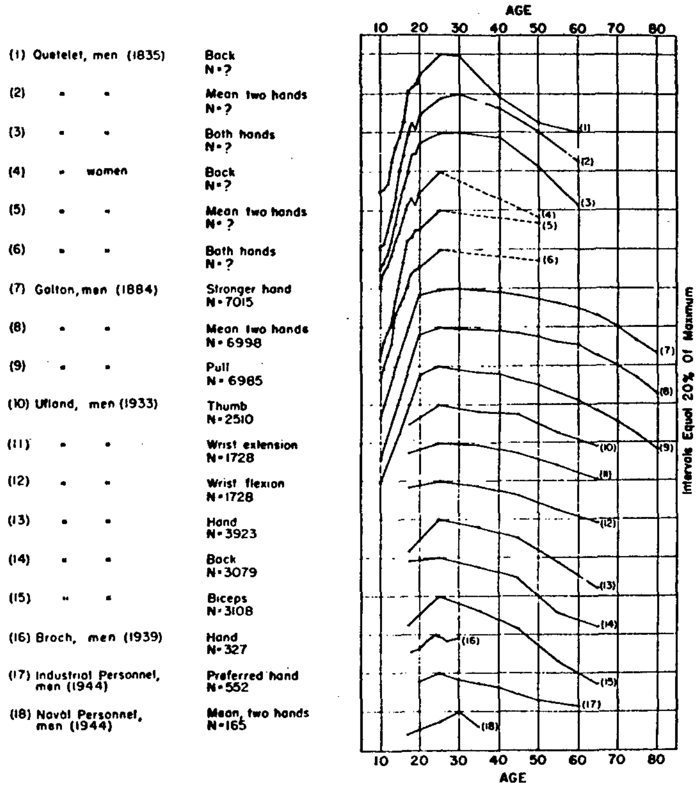


FIGURE 96 - 1

Relationship of Strength to Age. Values are Plotted as Per cent of the Maximum. Each Curve is Drawn to a Different Baseline, Separated by 20% From the Next.

97. Fisher, Otto. Theoretical Fundamentals for a Mechanics of Living Bodies with Special Application to Man as Well as to Some Processes of Motion in Machines. (Theoretische Grundlagen fuer eine Mechanik der Lebenden Koerper.) Leipzig, March 1906. (Armed Services Technical Information Agency No. ATI-153668; Air Technical Intelligence Translation from the German.)

"This book is intended to give a comprehensive description of...investigations into the kinetics of the joint systems, and...demonstrate the state of motion and equilibrium in man, with a large series of applications so that these applications may form the general basis for a mechanics of living bodies."

The book is 257 pages long. The original report includes numerous tables, figures, and formulas. The bibliography contains 50 references. The annotation includes the following tables: (1) Values of the Ratios μ of the Masses of Individual Sections of the Human Body to the Total Mass of this Body; (2) The Weights, Masses, Locations of the Centers of Gravity, and Moments of Inertia of Individual Parts of the Human Body. (Measurements were obtained on a frozen corpse (N = 1), the appendages being separated at appropriate joints.)

TABLE 97 - 1

Values of the Ratios μ of the Masses of Individual Sections of the Human Body to the Total Mass of this Body for:

Head	0.0706	Trunk + head	0.4976
Trunk	0.4270	Lower leg + foot	0.0706
Upper thigh	0.1158	Entire leg	0.1864
Lower leg	0.0527	Lower arm + hand	0.0312
Foot	0.0179	Entire arm	0.0648
Upper arm	0.0336	Both legs	0.3728
Lower arm	0.0228	Both arms	0.1296
Hand	0.0084	Trunk + head + both arms	0.6272

TABLE 97 - 2

The Weights, Masses, Locations of the Centers of Gravity, and Moments of Inertia of Individual Parts of the Human Body

Body parts		Weight in kg.	Mass number	Length l in cm.	Distance of the center of gravity: e_1 from above in cm.	e_2 from below in cm.	Radii of inertia κ and moments of inertia $m\kappa^2$ for axes through the center of gravity — Axis perpendicular to the longitudinal axis of the limb: κ in cm.	$m\kappa^2$	Axis parallel to the longitudinal axis of the limb: κ in cm.	$m\kappa^2$
Trunk + head		23.790	0.02425	72.75	42.61	30.14	21.08	10.7750		
Trunk		19.910	0.02029	56.75[1]	34.50	22.25	16.73	5.6819		
Head		3.880	0.00396	16.0[2]	11.93	4.07	6.81	0.1834		
Entire lower extremity	r	7.840	0.00799	78.9	32.74	46.16	25.10	5.0344		
	l	7.640	0.00779	79.2	32.42	46.78	25.08	4.8981		
Upper thigh	r	4.860	0.00495	35.9	15.72	20.18	11.01	0.6004	4.55	0.1025
	l	4.810	0.00490	36.65	15.90	20.75	11.43	0.6405	4.56	0.1019
Lower leg + foot	r	2.980	0.00304	43.9	(24.77	19.13	14.41	0.6305)[6]		
	l	2.800	0.00285	43.1	21.94	21.16	15.10	0.6507		
Lower leg	r	2.070	0.00211	37.9	16.13	21.77	9.16	0.1770	3.12	0.0205
	l	1.890	0.00193	37.1	16.30	20.80	9.66	0.1798	3.05	0.0179
Foot	r	0.910	0.00093	Height 6.0 Length 20.0[3]	6.38	13.62	5.91	0.0324	6.21	0.0358
	l	0.910	0.00093	Height 6.0 Length 20.0[3]	6.95	13.05	5.97	0.0331	6.24	0.0361
Entire upper extremity	r	2.360	0.00245	59.0	25.18	33.82	18.38	0.8127		
	l	2.470	0.00252	58.5	27.17	31.33	17.60	0.7798		
Upper arm	r	1.243	0.00127	25.5	11.37	14.13	7.95	0.0801	2.79	0.0099
	l	1.252	0.00128	27.1	12.31	14.79	7.79	0.0774	2.74	0.0096
Lower arm + hand	r	1.117	0.00114	36.0[4]	15.99	20.01	10.43	0.1238	2.75	0.0086
	l	1.205	0.00123	35.5[5]	17.02	18.48	11.24	0.1551	2.71	0.0090
Entire body		44.057	0.04491	150.5						

1) The length of the trunk means here the distance between the middle of the atlanto-occipital joint and the line connecting the two hip joint centers.

2) The length of the head means the distance from the top of the head to the middle of the atlanto-occipital joint.

3) The length of the foot means the distance of the tips of the toes from the axis of the upper ankle joint.

4) Of this, 24 cm were the length of the lower arm, and 12 cm the distance of the first interphalangeal joint from the hand joint.

5) Of this, 25 cm were the length of the lower arm, and 10.5 cm the distance of the first interphalangeal joint from the hand joint.

6) These four values were not obtained by direct measurements, but only later by some roundabout way: therefore, these values cannot claim the same accuracy as the others.

98. Frank, Wallace E. and Robert J. Gibson. A New Pressure-Sensing Instrument. Journal of the Franklin Institute, Volume 258, No. 1, July 1954, pp. 21-30.

"This paper describes work done in developing a system for measuring the pressure which is exerted by an individual on his environment. The requirements are that the range of sensitivity shall be the same as that expected to exist between an individual and the ground on which he may be lying or various portions of his clothing or equipment; the interposition of the pressure-sensing elements should not appreciably change the load distribution; and relatively high geometric resolution should be possible so that accurate pressure contours may be drawn, particularly in the neighborhood of bony prominences.

"The original concept of such a system basically covered the use of an array of pressure-sensing elements of capacitor or resistance type, mounted in a flexible blanket electrically connected to instruments which measured the changes in their electrical properties as the result of external mechanical forces. Two of these pressure-sensing blankets or arrays of Filpips, each consisting of 18 elements 1 sq cm in area and 1 in. between centers, have been constructed. Also developed and constructed have been unit electronic accessory boxes containing an oscillator, a bridge, a measuring instrument and necessary accessories for use with the pressure-sensing elements. Attempts have been made to manufacture the units so that all of the pressure-sensitive capacitors may be used with the same bridge to secure readings...within 10 per cent of the actual pressure. ...While the present units are sufficiently advanced for many applications, other schemes are under development for further reducing the error resulting from hysteresis."

The article is nine pages long and includes seven figures. There is no bibliography.

99. Hedberg, R.D. and C.M. Lobron. The Maximum Torque a Man Can Apply to a 1-1/8 Inch Knob. Human Engineering Report No. 5 (Report No. 4065), Frankford Arsenal Laboratory, Ordnance Corps, 2 June 1954 (ASTIA No. AD-52903).

The purpose of this experiment was to determine "the maximum turning force which could be exerted by the average man on a specific type of knob. The knob, as specified, had a diameter of 1-1/8 inches, was roughened with a medium diamond knurl, protruded 3/8 of an inch from a vertical flat surface, and was to be used for locking purposes at bench level.

"Thirty-three male subjects were chosen from available laboratory personnel. Their ages ranged from 22 years to 35 years (mean age = 29.2 years, standard deviation = 4.2). Pre-experimental trials showed maximum force could be applied in turning the knob by gripping it with the thumb and forefinger... . This grip was used throughout the test trials by all subjects... . All subjects were standing during experimental trials. The distance from the floor to center of the knob was 57-5/8 inches."

The apparatus consisted of a rod with one end machined in knob form, a lever arm and a Hunter Spring scale (Model LO-5). The applied force (in pounds) was calculated by multiplying the spring scale reading (in pounds) by the ratio of the lever arm (measured from the center of the rod) to the radius of the knob.

"For the thirty-three subjects tested, the average maximal force that could be exerted on this knob clockwise was 19.4 pounds with a standard deviation of 4.5 pounds..... In this case the mean minus one standard deviation will include about 84% of a normal population (the present subject population tested conforms to a normal distribution). The minus two standard deviations will include about 98% of a normal population."

It was concluded that, "from a practical standpoint, on this particular knob, (1) 84% of a comparable male population can be expected to exert a turning force of 14.9 pounds or more on this given knob, (2) 98% of a comparable male population can be expected to exert a turning force of 10.4 pounds or more on this given knob."

The nine pages of this report include two tables, two photographs and no bibliographic references.

100. Hertzberg, H.T.E. and Gilbert S. Daniels. <u>The Center of Gravity of a Fully-Loaded F-86 Ejection Seat in the Ejection Position</u>. Memorandum Report, No. MCREXD-45341-4-5, U.S.A.F., Air Material Command, Wright-Patterson Air Force Base, Dayton, Ohio, 14 March 1950.

The purpose of the work described in this report was "to determine the center of gravity of the F-86 Ejection Seat in ejection position when loaded with a pilot wearing full flying equipment.

"A rig was constructed to suspend the F-86A Ejection Seat (Assembly No. 151-53008) from a horizontal axis by means of two pairs of metal straps, one pair of which could be varied in length (see Figure 100 - 2). A plumb-bob dropped on one side of the seat from the intersection of the two straps was allowed to cross a metal plate rigidly mounted on the seat and accurately located with respect to Seat Reference Point. Because the seat was symmetrically suspended in reference to its longitudinal vertical plane, it was necessary only to determine the cg in the parallel plane containing the plumb-bob. The intersection of the plumb lines for the short and long positions of the rear pair of suspension straps gives the cg for any condition of load... ."

The subjects (N = 9) were tested in the rig. "Each subject wore full equipment consisting of a B-10 back-pack parachute with a seat style sustenance kit (Type A-1, for very cold climate), heavy winter flying clothes, Type A-6A heavy flying boots and a P-1 helmet... . Equipment weight totalled 59 1/4 pounds.

"The subjects averaged 69.2 inches in height (range, 65 to 73 1/4 inches) and 160.5 pounds (range, 119 3/4 to 196 1/2 pounds). All measurements were with street clothes and shoes. In both weight and stature the sample represented virtually 100% of Air Force flying personnel. (Ed. Note: Of the data then available.)

"The mean weight of men and equipment was 219.8 pounds with a range from 179 to 255 3/4 pounds.

"The average cg of nine subjects in ejection position in the F-86A ejection seat was located at a point 13 3/16 inches from the back of the seat and 15 7/8 inches from the bottom of the seat pan. For the lighter-than-average men in this series the average cg was located approximately 1/4 inch aft and 1/4 inch below that point. For the average of the heavier men in this series the cg was 1/4 inch above and 3/8 inch forward of that point. The cg of the loaded seat thus travels roughly 7/8 inch along a line whose angle is approximately 30° from the seat pan. It should be noted that the cg for any subject will depend on his weight, overall size, and the dimensions and cg of his body members. The apparent cg also may vary as much as 1/2 inch in large men with the variation of buttock position of the subject on the seat. For the present series the range of cg falls within a 1 1/8 inch radius of the average location, as is shown in Figure 100 - 1."

The report is six pages long. There are four figures, but no tables or references.

101. Hugh-Jones, P. <u>The Effect of Limb Position in Seated Subjects on Their Ability to Utilize the Maximum Contractile Force of the Limb Muscles</u>. Journal of Physiology, Vol. 105, 1947, pp. 332-344.

This report describes experiments designed to determine how the maximum pull or push exertable on an isometric[1] hand control, and the maximum push exertable on an isometric foot-pedal, vary with different control positions relative to a seat. It is shown that, in general, push or pull increases with extension of the acting joint until a maximum is reached just before the joint becomes straight.

[1] The author designed his experimental apparatus so that the amount of travel of the control, foot pedal or hand lever, was always the same for a certain magnitude of applied force. He used the principle of moments about an axle. "Thus the push or pull was practically 'isometric' in character," ('isometric' meaning essentially equal measure, that is, no change in the subject's relation to the control during application of the force).

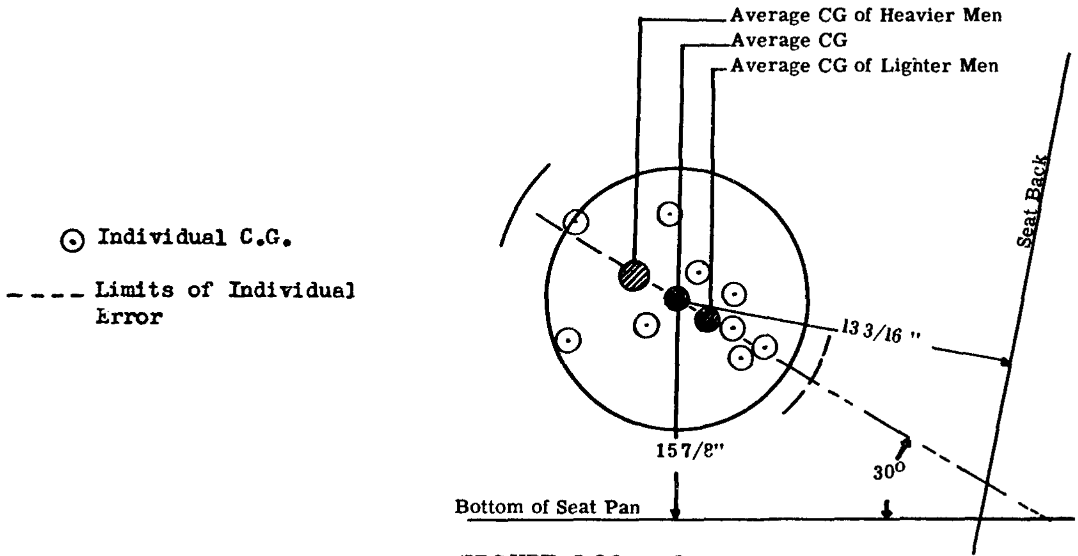


FIGURE 100 - 1

Location of CG

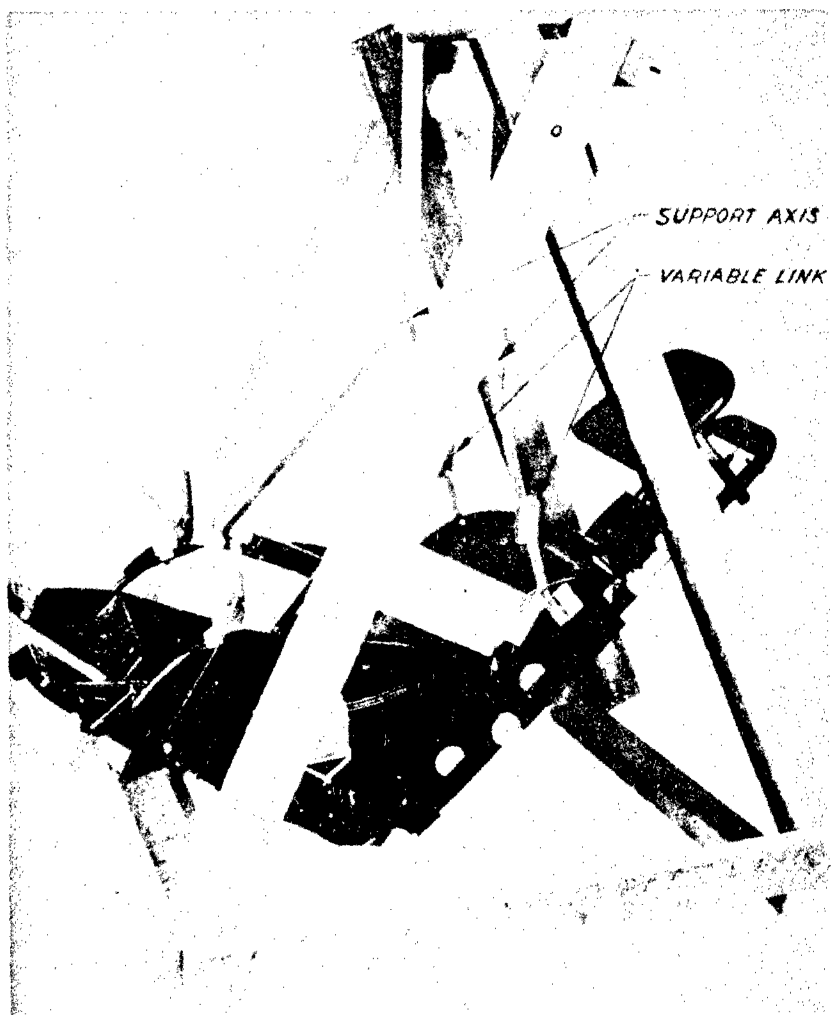


FIGURE 100 - 2

Ejection Seat in Rig

For the maximum push on the foot-pedal, results were recorded for six male subjects. Their ages ranged from 21 to 36 years and weights from 147 to 182 lbs. In order to compare one subject with another the seat was adjusted, to allow for differences in leg length, so as to give the same joint-angles at maximum push. For the maximum horizontal push on hand-lever, and all others than the maximum push on the foot-pedal, only two of the six subjects were used. Their weights were 168 and 172 lbs., ages 27 and 26 years, heights 71 and 70 inches respectively. "...the six subjects were powerfully built and not a representative sample of the (general) population."

For pushing on a control, against a seat back-rest, the findings agree with the theory that the limb acts as a mechanical "toggle" between the control and the back-rest. This toggle-action markedly increases the exertable push, and the relationship between control and seat becomes highly critical; it was found that the action is stopped at a well-defined "limiting angle" and that the effect was more pronounced in the lower limb. The "limiting angles" found were 160° for knee-extension and, approximately, 135° for elbow-extension.

TABLE 101 - 1

Mean maximum push exertable by six subjects on an isometric foot-pedal in positions allowing different degrees of extension of the knee-joint (angle β) for five approximately constant values of thigh-angles to the horizontal (angle α). Using right leg only.

Mean leg-angles recorded during maximum push (degrees)		Mean maximum push of six subjects ± 2 x S.E. (lb.)
Thigh-angle (α)	Knee-angle (β)	
- 6	94	73± 4.0
-15	149	227±20.8
-10	162	385±33.0
-10	165	346±20.2
- 9	167	250±34.4
+ 3	93	87± 6.7
10	136	270±30.6
5	164	559±35.4
19	67	89± 5.4
17	117	212±28.0
16	129	319±27.8
17	151	684±38.6
15	160	845±35.4
15	166	640±57.2
15	169	530±38.6
36	88	135± 5.2
33	106	184± 8.6
34	125	443±44.6
48	72	133± 7.2
49	81	130± 7.0

TABLE 101 - 2

The Mean maximum horizontal push on an isometric vertical hand-lever at different distances from the seat back-rest; for the lever in four different planes but with the hand-grip at a constant height of 15 in. above the seat level.

Vertical plane of lever	Distance from centre of hand-grip to seat back (in.)	Mean maximum horizontal push ± 2 x S.E.(10) (lb.) Subject 1	Subject 2
1. Left shoulder (using left arm)	17	64.3±3.8	57.5±2.0
	23	83.7±2.9	61.3±3.4
	29	111.1±4.2	77.6±3.8
	33	93.7±2.9	67.2±3.9
2. Mid-line (using right arm)	17	98.9±4.0	46.1±2.5
	23	107.4±7.1	57.6±5.0
	29	116.3±6.0	93.9±5.1
	33	99.5±1.9	77.0±2.3
3. Right shoulder (using right arm)	17	99.2±4.1	54.5±1.8
	23	109.0±4.6	60.9±2.5
	29	126.6±4.1	91.9±4.6
	33	107.8±7.0	72.6±2.6
4. Outside shoulder 14 in. to right of mid-line (using right arm)	17	64.8±4.7	——
	23	85.8±4.7	64.0±3.8
	29	108.2±4.0	74.4±4.0
	33	106.3±3.7	66.5±2.5

TABLE 101 - 3

Mean maximum horizontal pull on an isometric hand-lever for different heights and distances of the latter in relation to a seat. All results are for the right arm with the to-and-fro plane of pull through the shoulder.

Height of centre of grip above seat level (in.)	Distance from centre of grip to seat back (in.)	Mean maximum horizontal pull ± 2 x S.E. (10) (lb.) Subject 1	Subject 2
3	11	29.4±1.0	22.0±5.5
	17	37.8±5.0	31.5±3.4
	23	51.7±5.0	45.7±3.9
	29	59.5±3.9	58.3±6.2
	35	67.6±3.5	60.6±6.3
9	11	36.7±4.4	30.9±5.1
	17	48.0±5.0	40.2±6.2
	23	65.4±3.0	56.7±4.2
	29	71.2±5.0	67.5±7.4
	35	80.0±5.0	74.0±6.2
15	11	41.5±4.5	33.6±3.2
	17	57.4±3.9	50.4±4.3
	23	67.3±4.1	57.9±5.0
	29	74.8±3.4	63.8±9.6
	35	77.6±3.0	72.2±4.3
21	11	47.8±4.0	37.5±4.5
	17	61.1±3.3	56.1±3.3
	23	65.9±3.1	63.6±3.2
	29	66.1±2.2	65.5±3.7
	35	74.7±2.2	72.3±2.3

TABLE 101 - 4

Mean maximum pull on an isometric hand-lever with direction of pull at 45° upwards, but at right angles to the lever, for grip at different distances and heights in relation to the seat. All results for the right arm with the to-and-fro plane of pull through the shoulder.

Distance from centre of hand-grip to seat back (in.)	Height of centre of grip above seat level (in.)	Mean maximum pull ± 2 x S.E.(10) at 45° upwards (lb.)	
		Subject 1	Subject 2
17	- 6	80.6±4.7	86.5±3.5
	+ 7	—*	—*
	+13	73.4±2.1	79.4±1.7
	+19	—*	—*
23	- 6	98.9±3.1	95.0±4.8
	+ 7	—*	—*
	+13	72.8±2.8	78.6±2.1
	+19	58.8±3.2	53.4±1.3
29	- 6	102.5±2.0	98.3±4.8
	+ 7	95.4±2.9	93.7±2.6
	+13	74.3±2.7	73.7±1.8
	+19	53.2±2.2	50.3±2.7
35	- 6	102.0±1.6	92.3±2.9
	+ 7	77.4±2.4	82.6±2.5
	+13	62.7±1.9	65.3±1.6
	+19	47.9±2.9	49.0±0.75

* No readings possible with the apparatus for these positions.

For an isometric foot-pedal placed in front of a seat, maximum push is attainable when the subject's thigh is about 15° to the horizontal and his knee is extended just to reach the limiting angle. Possible leg push increases rapidly "until a well-defined "limiting angle" is reached at 160° for angle β; above this angle push suddenly decreases ...."

For an isometric hand-lever, maximum pull or push is attainable when the elbow is extended up to the limiting angle, the hand-grip is about at elbow height for the seated subject, and the lever moves in a vertical plane which passes through the shoulder-joint. The "limiting angle" for maximum arm action was found to be approximately 135° of elbow extension.

"To exert pressure between an isometric hand-grip and a seat back-rest is subjectively very unpleasant, though the exertable push, owing to toggle-action, is greater than the pull under comparable conditions. For reasons given, it is concluded that the conventional 'pull-on' hand-brakes for vehicles are preferable to a 'push-on' variety."

The author's report contains three illustrative figures, five tables of data and a list of ten references.

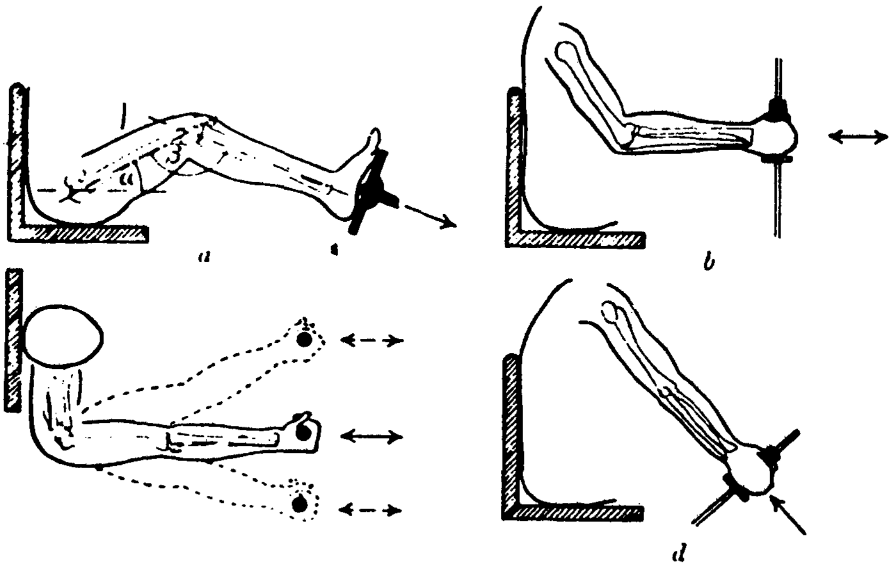


FIGURE 101 - 1

Diagram illustrating the different conditions under which the maximum force that could be exerted by a seated subject on foot and hand controls was determined.

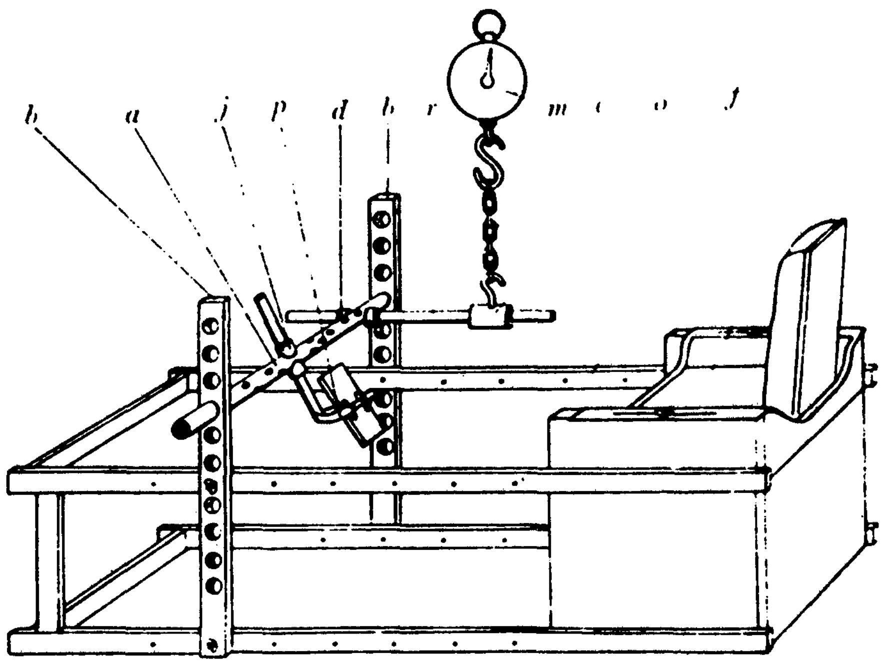


FIGURE 101 - 2

Diagram of frame apparatus which was modified for use in the different experiments described.

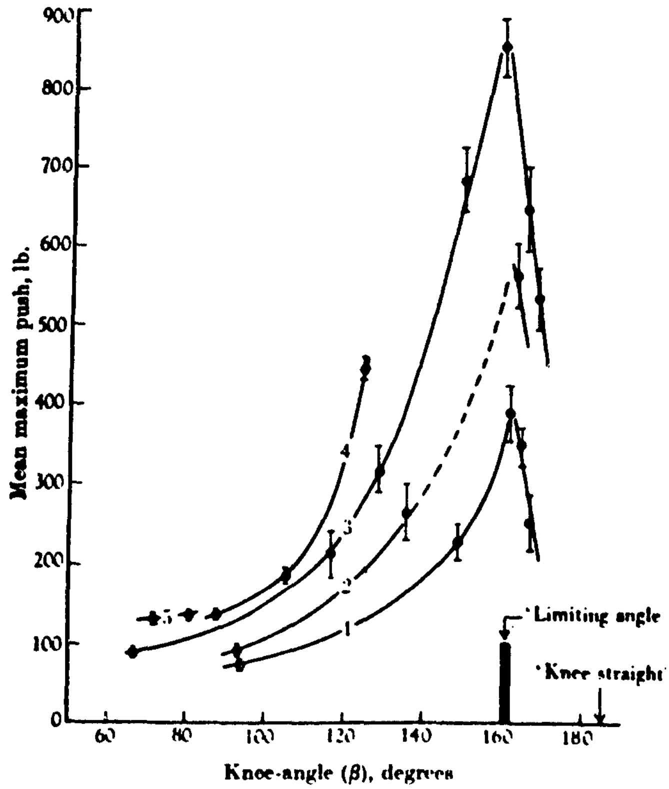


FIGURE 101 - 3

The mean maximum push (±2 x S.E.) exertable by six subjects on an isometric pedal placed in different positions that allowed different degrees of knee-extension (angle β) for each of five different angles of thigh to the horizontal. (Curve 1, thigh-angle (α) between -15 and -6°; curve 2, between +5 and 10°; curve 3, 15-19°; curve 4, 33-36°; curve 5, 48-49°.)

102. Jenkins, William O. The Accuracy of Pilots in Applying Pressures on a Wheel-type Control. Report No. TSEAA-694-3A. U.S.A.F., Headquarters, Air Materiel Command, Engineering Division, Aero Medical Laboratory, 4 September 1946.

Purpose: "This study was designed to determine the accuracy with which pilots are able to apply pressures on a wheel-type control operated laterally as a function of the magnitude of a number of pressures in order to gather information concerning pressures providing the best 'feel of controls'."

Apparatus: "An aircraft wheel (15.5 inches in diameter) was welded to a semi-rigid, steel shaft, and mounted so that it could be operated for aileron action. Pressures applied to the periphery of this wheel by both hands resulted in slight movements which were transmitted over light cables to a pivoted mirror. A light beam was reflected from this mirror to a screen calibrated in one-half pound units. Standard pressures of 1, 5, 10, 20, 30, and 40 pounds were employed... ."

Sample: AAF pilots (N = 20) were used as subjects. "Each subject was blindfolded and given practice trials prior to testing to acquaint them with the "feel" of the pressures. Fifteen successive trials were given in each of the two directions for each of the six pressures.

Results: "Consistency of performance was determined by computing the variability of each man's performance about his average. Relative consistency was found by dividing the variability measure by the standard pressure at each of the six points for both directions of control action. The difference between the standard and attained pressure was also computed.

"Variability of pressure reproduction increased directly as a function of the magnitude of the standard pressure.

"Relative consistency was found to improve rapidly from one to 10 pounds and to reach an asymptote near 20 pounds. Beyond this value and through 40 pounds the ratio of variability to standard pressure was roughly constant.

"Accuracy of performance was not appreciably different for the two planes of control action.

"This pilots tended to apply too much force for most pressures with the magnitude of error being greatest in the middle range of pressures.

"Relative and absolute accuracy of performance was superior at five of the six points for the group working with the wheel as compared with the previous findings for a group operating a stick-type control. The differences were not statistically significant... ."

The report is 11 pages long including an appendix, one table, one figure, and a bibliography of two items. The data are included in this annotation.

TABLE 102 - 1

Standard Deviations (SD), Difference Limens (DL),* and Constant Errors (CE) in Pounds for 20 Pilots Operating a Wheel-type Control Laterally

Pressure in lbs.	RIGHT			LEFT			COMBINED		
	SD	SD/S	CE	SD	SD/S	CE	SD	SD/S	CE
1	.22	.22	.13	.24	.24	.15	.23	.23	.14
5	.44	.09	.24	.45	.09	.22	.44	.09	.23
10	.66	.07	.26	.69	.07	.32	.67	.07	.29
20	1.22	.06	.25	1.17	.06	.30	1.20	.06	.28
30	1.86	.06	.28	1.51	.05	-.02	1.69	.06	.13
40	2.08	.05	.19	2.00	.05	.01	2.04	.05	.10

$* \text{ DL} = \frac{\text{SD}}{\text{Standard in Pounds}}$

103. Jones, Harold E. The Relationship of Strength to Physique. American Journal of Physical Anthropology, New Series, Volume 5, 1947, pp. 29-39.

The article noted that strength is related both to body size (especially to weight) and to the mesomorphic component in body build. Mesomorphy...from...present evidence has little or no relationship to weight, and is negatively correlated with height. As a result, exceptions occur to the "big and strong" classification, as in cases of boys who are big but weak, or small but mesomorphic and strong. Taken alone, weight accounts for only 25% of the variance in strength, whereas 75% of the variance is controlled when the components of body build are included with weight and height in proportions based on a multiple regression equation. In other words, static dynamometric strength is relatively independent of gross body size, but a combination of size and body build provide a fairly adequate representation of the factors determining strength.

The five figures and two tables present relevant data for this study and some somatotype material, such as intercorrelations (Pearsonian r's for these particular subjects) of strength and weight, height, endomorphy, mesomorphy and ectomorphy. Four bibliographic references are cited.

104. Karpovich, Peter V. and Creighton J. Hale. Physiology of Load-Carrying. IV. Pressure Exerted by Pack Straps as Related to Load Carried and Chest Dimensions. Environmental Protection Division, Report No. 213, Quartermaster Research and Development Command, Natick, Massachusetts, June 1953.

"Measurement of pressure. The pressure exerted by pack straps on the top of the shoulder, the clavicle, and the front of the shoulder was measured on 37 (N = 37) male college students carrying packs weighing from 20 to 70 pounds, in both the high and low positions. This pressure was measured while the subjects stood still and also while they walked on a motor-driven treadmill at a speed of 2.8 mph.

"Pressure meter. Strap pressure was measured by means of a device called a pressure meter, consisting of an aneroid sphygmomanometer and a pressure chamber calibrated in such a way that readings in millimeters from the manometer could be translated into pounds of strap pressure. This pressure meter can be used not only in the laboratory but while the subject walks outdoors. A series of tests made by two investigators had coefficients of correlation of $r = +.93$ during standing and $r = +.96$ during walking, indicating that the objectivity of this method is high.

"Strap pressure in standing. Strap pressure on the top of the shoulder is greater than that on the front of the shoulder, while pressure on the clavicle is equal to pressure on the shoulder top. The strap pressure in pounds on the top of the shoulder or on the clavicle may be expressed as $y = .15\ x$, where y is the strap pressure in pounds, and x is the pack weight. For example, the strap pressure for the 20-pound pack is three pounds and for a 70 pound pack it is 10.5 pounds. The strap pressure on the shoulder front is $y = .4 + .10\ x$. Thus, for a pack weighing 20 pounds, this pressure is 2.4 pounds; for a pack of 70 pounds, it is 7.4 pounds. The strap pressure on the top or the front of the shoulder is not affected by the nine-degree angle of inclination of the plane on which the subject stands. There is no difference in strap pressure between the low and high pack.

"Strap pressure in walking. The pressure on the top of the shoulder is equal to that on the clavicle, but is greater than the pressure on the front of the shoulder. The relation between the strap pressure in pounds (y) and the weight of the pack (x) may be expressed by the following formulas:

	Shoulder Top	Shoulder Front
	High or Low Pack	
Horizontal Plane	$y = 1.8 + .19\ x$	$y = 1.5 + .121\ x$
Upgrade	$y = 2.3 + .173\ x$	$y = 1.5 + .121\ x$
	Downgrade	
Low Pack	$y = 1.8 + .196\ x$	$y = 1.5 + .121\ x$
High Pack	$y = 2.3 + .173\ x$	$y = 1.5 + .121\ x$

"Relation between chest size and strap pressure. In general, with increase in chest size, the strap pressure on the shoulder top decreases, while that on the shoulder front increases.

"The use of the strap pressure measurement for evaluation of new designs of packs. By means of a pressure meter the strap pressure exerted by an experimental pack can be easily found, even without laboratory facilities, and compared with the pressure exerted by the old packs.

Conclusions:
"a. Measurement of strap pressure is the only objective quantitative evaluation of this pressure. Subjective reports are difficult to evaluate and often impossible to compare.

"b. It is sufficient to measure the strap pressure at two points only: the shoulder top and the shoulder front.

"c. A pressure measurement during standing gives an estimate of pressure during walking.

"d. Strap pressure on the shoulder front increases with the increase either in chest size or shoulder circumference while at the same time, the pressure on the top of the shoulder decreases."

The article is 26 pages long, including 18 tables and eight figures. There is no bibliography. The main data of the report are included in this annotation.

A - is the pressure chamber (details shown at A top) connected by means of rubber tubes (B) and (B_1) with a manometer (C) and a compression rubber bulb (D). For calibration, A is placed under a strap (F) attached to a yoke (G). By operating the windlass (J), a pressure of from one-half to 16 pounds in increments of one-half pound can be applied to the chamber. The amount of pressure will be indicated by the scale (H). From the recorded manometer readings and corresponding scale readings, the factor for converting millimeters into pounds will be obtained.

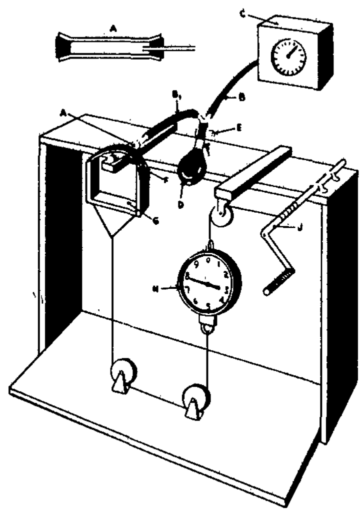


FIGURE 104 - 1

Pressure Meter and Device for Its Calibration

TABLE 104 - 1

Pressure (in pounds) of Pack Straps on Top of Shoulders During Standing

	Low Pack						High Pack					
	On a Horizontal Plane											
Weight of Load (pounds)	20	30	40	50	60	70	20	30	40	50	60	70
Mean	2.3	3.2	4.3	5.3	6.0	6.7	2.0	3.4	4.3	5.1	6.1	6.9
Std. Deviation	1.0	1.1	1.3	1.5	1.9	1.8	1.1	1.0	1.3	1.2	1.4	1.6
Std. Error of Mean	.2	.2	.2	.3	.4	.3	.2	.2	.2	.2	.2	.3
	Facing Downgrade											
Weight of Load (pounds)	20	30	40	50	60	70	20	30	40	50	60	70
Mean	2.3	3.2	4.1	5.0	5.8	6.6	2.2	3.1	3.8	4.6	5.5	6.2
Std. Deviation	.9	1.0	1.3	1.7	1.8	1.8	1.3	1.2	1.3	1.2	1.5	1.6
Std. Error of Mean	.1	.2	.2	.3	.3	.3	.3	.2	.2	.2	.3	.3
	Facing Upgrade											
Weight of Load (pounds)	20	30	40	50	60	70	20	30	40	50	60	70
Mean	2.5	3.3	4.1	5.0	5.9	6.8	2.5	3.3	4.3	5.3	5.9	6.7
Std. Deviation	.8	.8	1.0	1.3	1.2	1.4	.9	1.0	1.1	1.7	1.7	2.0
Std. Error of Mean	.1	.1	.2	.2	.2	.2	.2	.2	.2	.3	.3	.3

TABLE 104 - 2

Pressure (in pounds) of Pack Straps on Front of Shoulders During Standing

	Low Pack						High Pack					
	On a Horizontal Plane											
Weight of Load (pounds)	20	30	40	50	60	70	20	30	40	50	60	70
Mean	3.0	4.4	5.9	7.4	8.7	10.0	3.3	4.8	5.8	7.3	8.3	9.7
Std. Deviation	1.4	1.4	1.8	2.2	2.5	2.9	1.1	.8	1.5	1.8	1.9	2.2
Std. Error of Mean	.2	.2	.3	.4	.4	.5	.2	.1	.3	.3	.3	.4
	Facing Downgrade											
Weight of Load (pounds)	20	30	40	50	60	70	20	30	40	50	60	70
Mean	3.0	4.7	5.9	7.3	8.7	10.1	3.0	4.5	5.8	6.9	8.1	9.3
Std. Deviation	.9	1.1	1.3	1.6	1.9	1.9	.9	1.1	1.1	1.5	1.8	1.9
Std. Error of Mean	.1	.2	.2	.3	.3	.3	.1	.2	.2	.2	.3	.3
	Facing Upgrade											
Weight of Load (pounds)	20	30	40	50	60	70	20	30	40	50	60	70
Mean	3.2	4.7	6.1	7.7	9.0	10.7	3.4	5.0	6.4	7.9	9.2	10.7
Std. Deviation	1.1	1.4	1.7	2.4	2.5	2.6	.9	1.3	1.5	1.9	2.1	2.7
Std. Error of Mean	.2	.2	.3	.4	.4	.4	.1	.2	.2	.3	.4	.4

TABLE 104 - 3

Pressure (in pounds) of Pack Straps on Front of Shoulders During Walking

	Low Pack						High Pack					
On a Horizontal Plane												
Weight of Load (pounds)	20	30	40	50	60	70	20	30	40	50	60	70
Mean	3.7	5.2	6.3	7.5	8.5	9.6	4.0	5.3	6.4	7.6	8.7	9.8
Std. Deviation	1.0	1.4	1.6	1.8	1.9	2.3	1.2	1.4	1.5	1.6	1.9	2.7
Std. Error of Mean	.2	.2	.3	.3	.3	.4	.2	.2	.3	.3	.3	.3
Downgrade												
Weight of Load (pounds)	20	30	40	50	60	70	20	30	40	50	60	70
Mean	3.9	5.1	6.2	7.6	8.8	10.0	3.9	5.0	6.2	7.2	8.5	9.6
Std. Deviation	1.2	1.6	1.8	2.1	2.4	2.5	1.4	1.6	1.7	1.9	2.3	2.2
Std. Error of Mean	.2	.3	.3	.4	.4	.4	.2	.3	.3	.3	.4	.4
Upgrade												
Weight of Load (pounds)	20	30	40	50	60	70	20	30	40	50	60	70
Mean	3.6	4.8	6.0	7.1	8.3	9.4	3.7	5.0	6.3	7.3	8.5	9.3
Std. Deviation	.9	1.1	1.4	1.6	1.9	2.2	1.2	1.7	1.9	2.1	2.4	2.9
Std. Error of Mean	.2	.2	.2	.3	.3	.4	.2	.3	.3	.3	.4	.5

TABLE 104 - 4

Comparison of Pressure Exerted by Straps of High and Low Packs During Walking on a Horizontal Plane or Upgrade or Downgrade.

Pack Wt. (lbs.)	D = Difference between Means t = t-ratio	Horizontal Plane	Upgrade	Downgrade
Pressure on Shoulder Top				
20	D t	-.3 .38	-.1 .25	.0 .05
30	D t	-.2 .45	-.2 .50	.1 .25
40	D t	-.2 .26	-.3 .47	.3 .56
50	D t	.4 .63	.1 .20	.7 1.36
60	D t	.0 .08	-.2 .18	.9 1.90*
70	D t	.1 .31	.3 .18	1.0 1.84*
Pressure on Shoulder Front				
20	D t	-.3 .92	-.1 .22	.0 .07
30	D t	-.1 .25	-.2 .46	.1 .18
40	D t	-.1 .29	-.3 .82	.0 .00
50	D t	-.1 .4	-.2 .51	.4 .89
60	D t	-.2 .64	-.2 .39	.3 .60
70	D t	-.2 .56	.1 .18	.4 .79

*Indicates that difference between means, D, was statistically significant.

NOTE: Positive difference between means indicates that pressure while walking with the low pack was greater than pressure while walking with the high pack.

TABLE 104 - 5

Correlations Between Strap Pressures and Certain Anthropometric Measures During Standing and Walking on a Horizontal Plane

Measures	Strap Pressures							
	Standing				Walking			
	High Pack		Low Pack		High Pack		Low Pack	
	S.T.	S.F.	S.T.	S.F.	S.T.	S.F.	S.T.	S.F.
Bi-Acromial Diameter	.0162	.1325	-.2096	.3080*	.0564	.1931	-.1838	.2821*
Chest Width	-.0747	.3396*	-.3692*	.1802	-.1647	.3728*	-.3539*	.1938
Sternal Length	-.1184	.0774	-.3819*	.0894	-.2091	.1835	-.3194*	.1669
Chest Depth	.1295	.2834*	-.2094	.1720	.0803	.2527	-.2629	.1886
Chest Circumference	-.1725	.4176*	-.3599*	.2652	-.1300	.3909*	-.4082*	.2536
Shoulder Circumference	-.0522	.4308*	-.3605*	.1070	-.1349	.3722*	-.3768*	.1202
Body-Strap Contact	.0753	.0325	-.2284	.0868	-.0331	.0756	-.2330	.1300

*Indicate statistical significance at the .05 level.

S.T. - Shoulder Top
S.F. - Shoulder Front

TABLE 104 - 6

Comparison of Strap Pressure Exerted by an Experimental Combat-Cargo Pack and by Low and High Packs Carried on a Packboard (Pressure in Pounds)

Activity	Experimental Pack	Pack on a Packboard	
		Low	High
Shoulder Top			
Walking, Horizontal	8.66	10.13	10.29
Upgrade	8.23	9.99	10.58
Downgrade	10.29	11.03	9.99
Shoulder Front			
Walking, Horizontal	4.40	6.43	7.24
Upgrade	5.89	5.39	5.18
Downgrade	6.13	5.65	4.82

NOTE: Both packs weighed 40 pounds.

105. Martin, William B. and Edward E. Johnson. An Optimum Range of Seat Positions as Determined by Exertion of Pressure upon a Foot Pedal. Report No. 86, (Subtask under Human Engineering Studies, AMRL Project No. 6-95-20-001, Subtask, Control Coordination Studies), Army Medical Research Laboratory, Fort Knox, Kentucky, 15 June 1952.

The object of this study was "to determine an optimum range of seat positions for exertion of pressure upon a foot pedal.

"Tests on 166 men with anthropometric measurements representative of Army male personnel in general revealed that:

"1. For the positions in which the most pressure was exerted (25 per cent of total positions tested) the mean vertical adjustment of the pedal was 2.4 inches above the seat and the mean horizontal adjustment from seat to pedal was 33.2 inches.

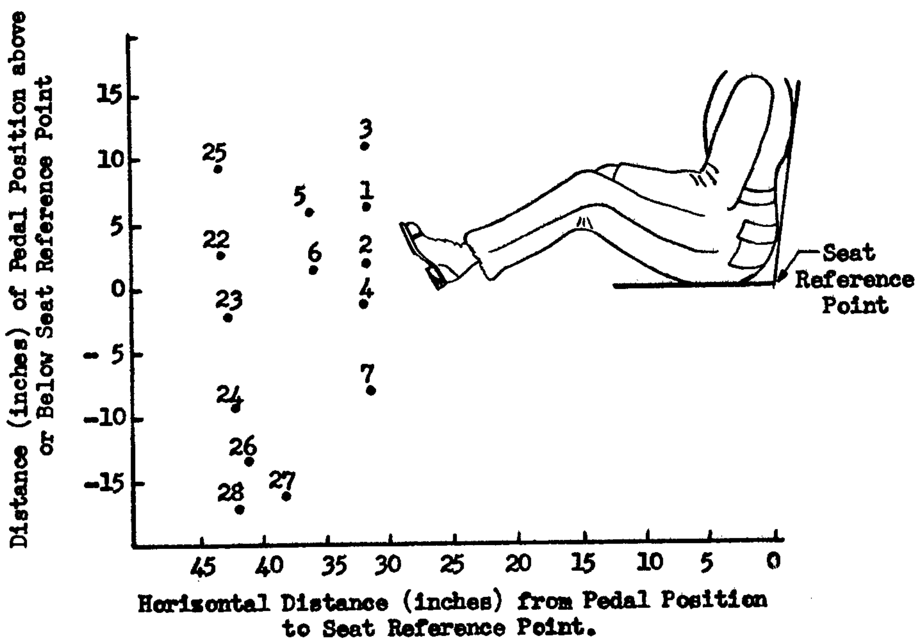


FIGURE 105 - 1

The Best and Worst Seat Positions
(1- 7- Rank Number of Best Positions)
(22-28- Rank Number of Worst Positions)

"2. The mean vertical adjustment for the position at which most foot pressure could be applied was 3.5 per cent of the average body height (SD = 2.7%) and the mean horizontal adjustment was 47.5 per cent of the average body height (SD = 2.3%).

"3. In generalizing for the average height of Army male personnel (68.4 inches) the position at which the greatest pressure could be exerted upon a foot pedal would require a vertical distance from seat to pedal of 2.4 inches plus or minus 0.3 inch, and a horizontal distance of 32.5 inches plus or minus 4.25 inches."

It was concluded, "1. In the optimum positions for exertion of pressure upon a foot pedal the pedal is slightly above the level of the seat.

"2. Changes in horizontal seat-to-pedal distance affect the foot pressure more than like changes in vertical seat-to-pedal distance.

"3. An optimum range of seat-to-pedal distances can be related to body height."

The nine pages of this report include two figures, three tables and three bibliographic references. The figure presented in the annotation has been adapted from the report.

106. McAvoy, William H. Maximum Forces Applied by Pilots to Wheel-type Controls. National Advisory Committee for Aeronautics, Technical Note No. 623, Washington, November 1937. (Armed Services Technical Information Agency No. ATI-93620.)

"Measurements were made of the maximum push, pull, and tangential forces that could be applied to airplane wheel-type controls for a wide range of fore-and-aft positions of the wheel. The measurements were conducted with several sizes of wheels and several heights of the center of the wheel above the seat. Various one- and two-hand grips with pilots both secure and free were studied for each of the two pilots used in the investigation, (N = 2).

Push and pull forces. "It will be noted that the tendency is for the push forces to peak with the wheel in a position about 24 inches from the back of the seat. It is also shown that the pilot can exert a greater pull force when in the secure position.

"In general, the forces for the pilot secure tend to be greater with the 16-inch wheel for both push and pull conditions. It is interesting to note that for the push forces the optimum wheel position is about 24 inches from seat, while pull forces increase steadily with the distance of the wheel from the seat.

"The effect of wheel height above the seat...shows a marked increase in push and pull forces with the wheel in the higher position over a large part of the range. For pull, however, the forces follow more closely for the two height conditions.

Tangential forces. "The variation of tangential force with wheel diameter shows that larger forces are obtained with the smaller wheel diameters for both clockwise and counterclockwise rotation... . It will be noted that minimum forces are obtained with the wheel in the extreme forward position.

"The tangential forces obtained with pilot secure and pilot free...are approximately equal with the wheel in the rearmost position but, as the wheel is moved forward, there is a definite decrease in the forces applied by the pilot in the secure position. This decrease is due chiefly to the fact that, as the wheel is moved away from the pilot, it becomes necessary for him to work with arms more extended, thereby cutting down on his mechanical leverage.

"The general trend of the forces as shown would indicate that the high wheel position is slightly favorable.

"The position of both hands on the sides of the wheel is considered to be the most common for normal flying, while both hands on top of the wheel is probably used as an alternate position. The quarter-turn of the wheel position (hands on top and bottom) was investigated principally to show the forces that can be applied when moving the wheel through the larger displacements.

It is interesting to note that for the clockwise rotation the greater force can be exerted by one hand, as against the two-hand position on top of the wheel. ...The reason for this difference is believed to be due to the more favorable position the pilot can assume in the one-hand position."

The report is five pages long; two tables and 19 figures are included. Two bibliographical references are given.

Editor's note: The work reported here is important historically, as it was incorporated into the designs of numerous aircraft built in the 1930's. The data, of course, are not to be considered useful for modern design, having been taken on only two subjects, and about 12th percentile subjects in stature, at that. Hence by no stretch of the imagination can they be considered representative of pilots as a whole. The use of an adjustable cockpit mock-up, however, is sound, and an adequate sample is essential for reliable data.

TABLE 106 - 1

The Physical Dimensions of the Two Pilots

Dimension	Average pilot (reference 2) (in.)	Pilot A (in.)	Pilot B (in.)
A	68.20	66.5	66.0
B	30.70	30.5	31.3
C	33.28	33.4	33.0
D	17.84	17.5	19.0
E	17.12	16.5	14.8
F	16.40	16.2	16.0
G	4.12	4.4	4.5
H	22.00	21.5	21.5
J	10.48	10.1	9.0
K	13.12	9.8	10.0
L	23.85	23.3	22.5
M	42.80	41.3	41.0
Distance between finger tips with arms spread (in.)		67.0	68.0
Weight without flying gear (lb.)		145.0	165.0

TABLE 106 - 2

Arrangement of Cockpit Controls

Dimension	U.S. Navy specification (in.)	U.S. Army Air Corps specification (in.)	Average of 7 N.A.C.A. airplanes (military and commercial) (in.)	Cockpit model used in tests (in.)
A	35 to 41	35-3/8 to 39-3/8	35 to 39	33-1/2
B	6 to 10	2-1/4 to 10-3/4	3 to 5	6
C	3 to 5	3-1/4	3 to 4	-
D	15 to 17	12 to 19-1/2	14 to 22	10 to 18
E	18 to 22	18	14 to 19	18
G	12 minimum	16-5/8	9 to 13	12
H	8° to 10°	13-1/2°	6° to 10°	14°
K	3°	-	5° to 12°	10°
Lateral distance, center to center, of rudder pedals		16-1/4	12 to 21	20

107. Müller, E.A. <u>Optimum Arrangement of Pedals to be Operated from Sitting Position</u>. Air Technical Intelligence Translation (from German), 182580, F-TS-3336/V, Air Technical Intelligence Center, Wright-Patterson Air Force Base, Ohio (no date). (ASTIA ATI-138641).

Using experimental equipment consisting primarily of an instrumented seat-pedal arrangement, this study analyzes the relationship between seat position and pedal force to determine the optimum arrangement of pedals to be operated form the sitting position.

Three subjects were utilized for this study and data for them are presented below:

Subject	Sex	Age	Weight in kg	Lengths in cm: Thigh (hip to knee) (Measured from gap in knee joint)	Lengths in cm: Leg (incl. height of foot) (measured from gap in knee joint to sole of foot)
A	♂	36	62	44	48
B	♀	24	65	44	44
C	♀	18	54	43	47

Fifty-eight different combinations of seat-pedal distance and seat height were investigated. To avoid fatique, only a few tests were scheduled each day and frequent rest periods were provided. A table of the measurements of the maximum force applied to the pedal is included in the original report.

"The greatest forces are obtained if the seat level is at the same height (± 10 cm) as the center of the pedal surface. The distance of the back rest from the center of the pedal surface must be 5 - 10 cm shorter than for the fully stretched leg. The back rest must offer immediate support to the pelvis. The foot must rest with its arch over the axle of a tiltable pedal. (The pedal must not be touched with the tip of the foot.) The direction in which the pedal moves must be downward and forward, forming a 75 - 80° angle against the vertical."

The report is 11 pages long and includes two tables and ten figures. One reference is listed.

108. Orlansky, Jesse and J.W. Dunlap. The Human Factor in the Design of Stick and Rudder Controls for Aircraft. Contract N6 ori-151, Project No. 20-M-1c, Task Order No. 1, Special Devices Center, Office of Naval Research, Port Washington, New York, 3 February 1948. (Armed Services Technical Information Agency No. ATI-25933.)

"1. This study is an attempt to determine how airplane control systems may be designed to provide the pilot with optimal sensory information by means of pressure cues obtained from operating the stick and rudder. The present approach to the problem consists of an examination and evaluation of literature pertaining to

(a) the maximum forces that may be exerted by a human pilot;
(b) human reaction time insofar as it may be expected to cause delays in the pilot's response;
(c) the optimal design, placement, and manner of movement of controls, and
(d) the optimal gradients of control forces.

"2. Current specifications for stability and control characteristics of military and civil airplanes are examined. They are found to lack the precision required for insuring controlled flight at all times, for preventing the forces from exceeding the pilot's strength, or for providing for consistent responses of the plane to various motions of the controls. The control force gradients that are specified permit variations in design not always desirable.

"3. The maximum force exertable by a pilot is found to depend on position of the hands and feet, type of control and the direction in which the force must be exerted. Except for certain positions close to the body, a pilot can easily exert and usually exceed the force limits set by current plane design specifications. That the pilot may sometimes be required to exceed the specified limits for a given plane is shown in certain flight test records.

"4. Sensitivity to changes in pressure varies in a non-linear fashion with absolute increases in pressure. This follows a psychological relationship generally found to describe the ability to discriminate sensory effects. This means that stick forces must increase geometrically with stick displacement and with speed in order to furnish the pilot with optimal pressure cues. Pressure sensitivity of the hands is poor at pressures below 5 pounds, and control movements are fatiguing above 35 pounds. The recommended ranges of control forces, for optimal accuracy and consistency of performance, are 5 - 30 pounds for stick, and 15 - 60 pounds for wheel and rudder. Friction forces of about 2 - 3 pounds on hand controls, and about 7 pounds on foot controls, are not undesirable."

"5. Hand controls are more precise than foot controls, but no difference is found between stick and wheel as far as efficiency of performance is concerned. Fore-and-aft hand motions are slightly more precise than right-and-left or rotary motions. Controls should be shaped for maximum convenience of grasp, and placed symmetrically with respect to the pilot, with hand controls at about elbow height. Increments of about 15% may be detected in the linear displacement of hand-operated controls, under constant load conditions.

"6. Simple reaction time to sound is slightly faster than to touch or light, and approximates 0.600 seconds for a complex task. Where descrimination and judgment are involved, about 1 - 2 seconds is required. The rate of motion of controls depends on the load, and appears to be higher for push than for pull motions.

"7. Stick force characteristics should be consistent for various types of aircraft. The response of the plane to control stick deflection should also be standard, consistent, rapid and smooth. There is doubtful value in maneuvering characteristics which so affect the pilot that he becomes disoriented. Stick forces should change with speed, acceleration and load to provide information and warning as stress limits are approached.

"8. Stick forces should increase geometrically with stick deflection. It is recommended that stick forces increase more rapidly at very slight and at very great stick deflections than equally over the extensive range between these extremes. At very slight deflections, although the absolute force is small, a rapid increase is needed to overcome the masking effect of friction; at very great deflections, it serves as a warning that the stress limit is being approached. The force vs. deflection gradient should be increased as the speed is increased. Thus, a family of curves should describe the force-deflection relationship at various speeds for a given type of plane. A quantitative description of these gradients is suggested but should be verified by flight tests.

"9. Various types of booster systems are described. It is recommended that if booster systems are employed, the desired stick-feel characteristics should be provided by artificial means.

"10. Experimental validation of all recommendations is urged."

The report is 69 pages long, including five tables and 21 figures. A bibliography of 75 references is included.

See also: Jenkins, William O. <u>The Accuracy of Pilots in Applying Pressures on a Wheel-type Control</u>. Report No. TSEAA-694-3A. U.S.A.F., Headquarters, Air Materiel Command, Engineering Division, Aero Medical Laboratory, 4 September 1946.

Additional references: Anonymous. <u>Stability and Control Characteristics of Airplanes</u>. U.S. Navy, Bureau of Aeronautics Specification SR-119A, 1945.
Jenkins, W.O. <u>The Accuracy of Pilots and Non-Pilots in Applying Pressures on a Control Stick</u>. U.S.A.A.F., Air Material Command, Engineering Division, Aero Medical Laboratory, Memorandum Report TSEAA-694-3, 15 August 1946.
Jenkins, W.O. <u>The Accuracy of Pilots in Applying Pressures on Rudder Pedals</u>. U.S.A.A.F., Air Material Command, Engineering Division, Aero Medical Laboratory, Memorandum Report, TSEAA-694-3B, 4 September 1946.
Anonymous. <u>Stability and Control Characteristics of Airplanes</u>. U.S.A.A.F., Specification No. 1815A, 7 April 1945, as amended 29 March 1946.

109. Reed, John D. Factors Influencing Rotary Performance. The Journal of Psychology, 1949, Volume 28, pp. 65-92.

"A light crank equipped with a counter was used to measure the maximal rate of turning under various conditions. The apparatus allowed variation in radius, braking force, position, and orientation of the crank. The measure of rotation rate was taken by recording the number of turns in five seconds.

"Four college students served as subjects, and each spent more than 1,200 five-second periods of rotatory work under a variety of conditions. Frequent rest periods and alternation of hands were both used to prevent fatigue. The following conclusions were reached:

1. The direction of rotation does not affect the rate.
2. As the radius is varied from 1.5 to 24 cm, the angular velocity is minimum at the largest radius and reaches a maximum about 2 cm. The radius at which this maximum occurs varies with the degree of coordination.
3. The linear velocity of the hand increases as the radius increases.
4. The preferred hand is not only faster but also maintains its maximum at shorter radii than the nonpreferred hand.
5. The greatest disparity between the preferred and nonpreferred hand is at the shortest radius.
6. There is a positive correlation between the rate obtained on preferred and nonpreferred hands.
7. In this rotatory performance, people differ more with respect to their nonpreferred hands than to their preferred hands.
8. No evidence of improvement in performance is apparent with either hand after more than 20,000 revolutions.
9. Short radii suffer more severely than larger radii from an increase in either torque or force required to turn the wheel.
10. Five subjects rotated the handle for four minutes with the nonpreferred hand and six with the preferred hand. The shortest radius suffered an initial rapid drop in rate, while the larger radii lost average angular velocity more gradually.
11. Change in the position of the crank has relatively little effect on the rate of rotation.
12. The highest rate may be obtained with the orientation of the crank such that motion takes place in a vertical plane parallel to the body. This position is not stable when a braking force must be overcome, in which case the orientation should be vertical and the plane of rotation perpendicular to the body."

This article is 27 pages long. It contains five tables and 13 figures. The bibliography lists five references.

110. Sandberg, K. O. William and Harold L. Lipshultz (New York University). Relative Performance for Cranking a Hand Wheel at Different Positions on a Vertical Surface. Report No. 166-I-22, Special Devices Center, Office of Naval Research, 20 April 1948.

"This investigation measured the speed with which subjects can crank a hand wheel at different positions on a vertical surface. Eleven male subjects were used. During all tests, the subjects were seated in a straight-backed chair whose back was 24 inches from the vertical surface. Test positions were spaced at 4-inch intervals vertically and horizontally and covered a total area of 44 inches (vertically) and 40 inches (horizontally).

"In general, the areas of best performance for the left hand were higher on the vertical surface than similarly rated areas for the right hand. The optimum areas (95% of maximum performance) for each hand are below eye level and on the same side of the body midline as the hand being used. The relative performance at all test positions is charted.

"No conclusive relationships were found between cranking performance and certain body dimensions of operators."

This report is 22 pages long and contains three tables and 10 figures. Three bibliographical references are given as footnotes.

111. Swearingen, John J. Determination of Centers of Gravity of Man. Final Report United States Navy Contract NAonr 104-51, C.A.A. Project No. 53-203, Civil Aeronautics Medical Research Laboratory, Aeronautical Center, Civil Aeronautics Administration, May 1953.

Purpose: "While a few isolated studies to determine the CG of the pilot have been made...a search of the literature reveals no comprehensive study for other body positions. This study is an attempt to fill this gap...and presents the center of gravity of the human body in sixty-seven different body positions. It is believed that this knowledge will be especially useful in controlling the body during free falls and parachute descents."

Equipment and Procedure: "A number of different techniques for locating and recording the CG were tested and the following chosen for use in this study. The equipment consists essentially of five platforms mounted one above the other. The top platform, which supports the subject, consists of an adjustable seat with arm and foot rests. The bottom of the seat, the foot rest and the arm rests are adjustable to different angles and can be counterbalanced in each position by a sliding weight on the back of the seat. This adjustable chair can be rotated about a horizontal axis from the horizontal to a second position through approximately 20° and locked in position. The second and third platforms slide horizontally at right angles to one another by means of jack screws. Each of these platforms also has its own counterbalance system, keeping the equipment as a whole in perfect balance regardless of position with reference to the bottom platform. The fourth platform is separated from the bottom by means of a ball and socket joint in the center and four electrical contact points, one at each corner. Each of these contact points lights a light in its corner if the platform is tilted in that direction. Hence, the platform may be assumed to be in balance when all four lights are out. A horizontal scale with one-fourth inch increments was mounted on the supporting structure of the tilt chair with its zero in vertical alignment with the reference point on the seat.

"A vertical cable was stretched taut from the ceiling to the base platform in front of the horizontal scale, and a camera sight set up approximately ten feet from the platform. The camera sight, vertical cable and ball and socket fulcrum were in alignment. A similar arrangement was placed at the end of the platform for reading lateral displacements of CG. The subject was then placed in the supporting structure with the seat back in the horizontal position, the equipment balanced by means of turning the jack screws and a reading taken on the horizontal scale. This reading represents the vertical height of the CG of the subject above the reference point when the subject is in normal upright sitting posture. The seat was then tilted approximately 20°, locked in position and rebalanced. The reading from the horizontal scale obtained as described above was then set on the base leg of a special adjustable T-square and the base of this T-square placed upon the seat back with the zero of the square at the line of intersection of the seat back and seat bottom. A second reading (the horizontal distance of the CG of the subject from the reference point) was then taken through the camera sight where the perpendicular member of the adjustable T-square intersected the vertical cable. By this method the location of the center of gravity of the subject was determined directly with reference to the seat.

"...It became apparent that if any point on the pelvic structure was chosen as a reference point the centers of gravity of all men fell in a very small area. For this reason all vertical distances to the centers of gravity are measured from the inferior spine of the ischium. Horizontal measurements are either from the anterior or posterior plane of the body, depending upon the type of motion involved. ...The sixty-seven different body positions studied are divided into three groups; sitting, maximum displacement of CG and the effects on the CG of adding various weights to the body.

Sitting: "Studies were made on three different sitting groups. The first group represents man in the normal sitting position, and presents data showing the effects upon the CG of moving the arms singly and in pairs. ...Two tests were made to show the shift of the CG when the trunk was flexed forward from the sitting position. The vertical height of the center of gravity is measured either from the seat bottom or from the ischium, as it was assumed that the ischium was in contact with the seat bottom. Horizontal distances to the CG in these tests are measured from the seat back.

"The second group concerns itself with the study of various pilot positions and shows the shift of CG if the arms are moved to various positions for operation of controls, with the legs at the comfort angle where the knees are 110° and in addition two extreme positions for the feet, one in which the feet are back under the chair and one where the legs are fully extended.

"The third group represents the airline passenger in the full reclining position and shows the displacement of the CG of the body when the arms are moved to various positions and when the feet are on the floor or on the foot rest. In this position the seat back makes an angle of 115° with the seat cushion.

Maximum Displacement of CG: "In this study of shift of the CG with maximum movements of the body the pelvis remains fixed and all movable body parts were shifted on the pelvis...the shift of the CG accompanying various anterior movements of body parts was studied. This included flexing the head forward, extending both arms straight forward, flexing the trunk forward, extending the legs straight forward and the final test in which all body parts were moved in unison to the maximum anterior position.

"For the posterior motions similar tests were made. These tests were made to determine the effect on the CG for posterior motions of head, arms, trunk, legs and all body parts moved in posterior direction.

"In the study of lateral shifts of CG, tests were made for location with the head flexed to the side, with the left arm extended laterally, with the right arm across the chest, with the head and trunk flexed to one side, with the left leg in maximum abduction, with the left leg abducted and right leg adducted, and a final test with all body parts moved laterally as far as possible.

"In tests to move the CG as far as possible toward the head (cephalad) tests for both arms extended over head and for both legs flexed toward the head, as well as one final test with both legs and both arms in maximum cephalad direction were made.

"Only two tests were made for shifting CG toward the feet (caudad), one with the subject standing with his trunk flexed as far as possible without extending the arms and the second with the arms extended.

"Finally, tests to determine the shifts of CG accompanying maximum abduction of arms and legs were made. ...Tests were made to determine the CG for abduction of the arms, for abduction of the legs and for simultaneous abduction of arms and legs.

Addition of Weights to the Body: "Studies were made to locate the CG of man sitting and standing with a twenty pound back pack on his back, with the CG of the pack 18-5/8 inches above the ischium and 6 inches posterior to the back. The CG of man wearing this pack in the two positions studied was found experimentally on the balancing equipment and then checked by mathematical calculations, using data previously obtained in this study of the CG of man without the pack. ...The calculated and the experimental data checked within one-fourth inch. The significance of these tests is obvious, as they show that the data presented in this report may be used as a basis for mathematical calculations of location of the CG of man in various positions with the addition of various weights to the body.

Sample: Since a large number of positions were studied, only a few men (N = 5) could be tested. These were carefully chosen to include a wide range of body sizes and weights. "Anthropometric measurements of these subjects are presented in Table 111 - 1. In addition to the five tested in all positions, an additional twenty-seven men were check-tested in one sitting and one standing position. In the sitting position the centers of gravity of all but one subject (97%) were found to fall within the range established for the original five subjects. In the standing position all but three (91%) fell within the established range.

Results: "The variation between subjects in any one position is sometimes greater than the shift of the center of gravity of the group due to any particular motion. The shifts of CG of all subjects follow a definite pattern.

"Analysis of tests of maximum shift shows that man is capable of shifting his CG roughly 11 1/2 inches toward the head, 10 inches toward the feet, 8 inches anteriorly, 4 1/2 inches posteriorly and 4 1/2 inches laterally.

"The maximum shift of CG accompanying the movement of all body parts in a given direction is not the sum of the shifts produced by moving each part separately."

The report is five pages long. Appended to it are 14 tables and 16 figures. A bibliography of four references is included.

TABLE 111 - 1

Anthropometric Measurements* of Original Subjects

	J.	B.	M.	N.	T.
1. Age	39	39	29	60	39
2. Weight	152	152	225	177	113.25
3. Stature	68	72	69.75	69.5	64.75
4. Sitting Height (Anthro.)	34.75	37.5	36.5	37	33.5
5. Trunk Height	23	24.5	24	22.5	23
6. Eye Level (Anthro.)	30	32.25	31	31.25	28.5
7. Buttocks Knee	23	24.5	24.5	23.5	22.5
8. Patella Height	21	22.25	22	20.75	19.75
9. Abdominal Girth	30.25	29	38	35	26
10. Thigh Circumference	18.75	18	24	20.75	15.5
11. Chest Depth	8	8.25	10.75	9.5	6.75
12. Abdominal Depth	7.75	7.5	10	9.5	6.5

*Weight in pounds; all other in inches

TABLE 111 - 2

Anthropometric Measurements of Subjects Used for Check Tests

Subject No.	Age	Weight	Stature	Sitting Ht. (Anthro.)	Trunk Height	Eye Level (Anthro.)	Buttocks Knee	Patella Height	Abdominal Girth	Thigh Circumference	Chest Depth	Abdominal Depth
1	39	165.5	68.5	36.25	24	32	24	20	30	18	9.75	9.25
2	53	205	72	38	23.5	33.5	25.75	22.25	34.5	19	11.75	10.25
3	39	216	70.5	36.5	23	32	25.5	22	41	19.5	12.5	12
4	41	118	69.75	35.5	21.5	31	24.5	21.5	28	15.5	9	7.5
5	36	146.5	68.5	35.75	24	32	23	20	31	18	8.5	8
6	50	174.5	64.5	32	22	29.5	22.25	19	36	20.5	10.5	9.5
7	41	164	70.75	32.25	21.75	30	25.5	22.5	31	20.25	9.25	8
8	39	151	74.75	36	25	33.5	25	22.75	28	18.5	9.25	7.25
9	35	224.5	70	36	25	32.5	23.5	20.75	37.5	23.5	11	10.25
10	38	164	61	31.25	22	28.5	19.75	18	36.25	29.5	11	10.75
11	57	160	70	36	21.5	30.25	23.75	21.5	33.5	19	9	9
12	35	202.25	67.75	36.25	23.5	31.5	22.5	19.5	36	22.25	10.25	10.25
13	29	133	67.5	35.25	22.5	30.75	21.75	20.25	31.75	17	8.25	7.25
14	43	175.75	67.5	35.75	23.25	31	22.5	20.5	37	20	10.25	9.75
15	44	153.5	69.25	36	24.5	32.5	23.5	20.75	29.75	19	9	7
16	43	145.5	66.25	35.5	24.25	31.5	22	19.5	31.5	19.25	8.25	8.5
17	35	150.5	65	34.25	23.25	30.5	21.75	18.75	32.75	20	8.5	8
18	33	135.5	66.5	34.75	23	30.5	22.5	19.5	28	18	8.5	7.5
19	29	167.25	73	38	25.25	32.75	24	22	30.5	29.25	10	8
20	33	137.5	68	35.5	23.5	30.5	23.5	20.25	27.75	18	7.5	7.25
21	33	167.25	72.5	38	24	33	24.25	22	32.25	20	8.5	8
22	45	194.5	68.75	36.75	23.5	32	22.5	20	37	21	9	10.5
23	29	134.25	69	37.25	24.25	32.75	21.5	20	24.75	18.5	8.25	6.5
24	35	177	69.5	38	23	31.75	23.5	20.25	31.75	21	9.25	9
25	31	153.25	69.25	35.25	21.5	30	24.75	21	29.5	18	9	8
26	24	147.25	72.5	37	23	31.5	24.25	22.5	28.75	18.5	9	7
27	30	137.75	69	36.75	24	31.75	23.25	20	25.5	18	7.5	6.5

TABLE 111 - 3

Sitting with Seat 90^{o} to Back, Legs 90^{o} to Thighs

Body Position	Location of Av. c. g.	Horizontal & Vertical Range For Subjects
A. Both arms down at sides	(8-3/8, 9-3/8)	± 7/8"
B. Both hands in lap	(8-7/8, 9-5/8)	± 7/8"
C. One arm forward, one hand in lap	(9-1/4, 10-1/8)	± 5/8"
D. Both arms straight forward	(9-3/4, 10-3/4)	± 7/8"
E. Both arms extended over head	(8-7/8, 12)	± 3/4"
F. One arm over head, one hand in lap	(8-5/8, 10-3/4)	± 3/4"
G. Both arms extended laterally	(8-1/8, 10-3/4)	± 3/4"
H. One arm extended laterally, one hand in lap	(8-3/8, 10-1/4)	± 3/4"
I. Both arms extended posteriorly	(8, 10-1/8)	± 7/8"
J. Trunk flexed on thighs, arms extended forward	(15-1/8, 5-3/16)	± 1-1/8"
K. Trunk flexed on thighs, arms down	(14-15/16, 5)	± 1-5/8"

TABLE 111 - 4

Sitting Back Erect, Seat 90^{o} to Back, Legs 50^{o} to Thighs

Body Position	Location of Av. C. G.	Horizontal & Vertical Range For Subjects
A. One hand on stick control, one on control at side of seat	(7-3/4, 9-7/8)	± 7/8"
B. One hand on overhead control, one on control at side of seat	(8, 10-1/4)	± 3/4"
C. Both hands on overhead control	(8-1/2, 10-9/16)	± 1"
D. Trunk flexed on thighs, arms around knees	(13-3/6, 4-7/8)	± 1"

TABLE 111 - 5

Sitting Back Erect, Seat 90^{o} to Back, Legs 110^{o} to Thighs

Body Position	Location of Av. C. G.	Horizontal & Vertical Range For Subjects
A. One hand on stick control, one on control at side of seat	(9-1/16, 9-7/8)	±7/8"
B. One hand on overhead control, one on control at side of seat	(9-5/16, 10-1/8)	±7/8"
C. Both hands on overhead control	(9-7/8, 10-9/16)	±1-1/8"

TABLE 111 - 6

Sitting Back Erect, Seat 108° to Back, Legs 180° to Thighs

Body Position	Location of Av. C. G.	Horizontal & Vertical Range For Subjects
A. One hand on stick control, one on control at side of seat	(9-7/8, 8-1/8)	± 1"
B. One hand on overhead control, one on control at side of seat	(10-3/8, 8-3/4)	± 1"
C. Both hands on overhead control	(10-9/16, 8-15/16)	± 7/8"

TABLE 111 - 7

Displacement of Body CG of Commercial Airline Passenger

Body Position	Location of Av. C. G.	Horizontal & Vertical Range For Subjects
Trunk 115° Knees 145°		
A. Hands in lap	(9-3/8, 7-3/4)	± 7/8"
B. Arms across chest	(9-5/8, 7-3/4)	± 3/4"
C. One arm forward	(9-3/4, 7-5/8)	± 1"
D. Both arms forward	(10-3/4, 8-1/8)	± 7/8"
E. Holding to seat back	(9-1/4, 9-1/8)	± 1"
F. Head and arms on forward seat	(12-1/4, 10-7/16)	± 5/8"
Trunk 115° Knees 90°		
G. Hands in lap	(7-7/8, 6-3/4)	± 1"
H. Arms across chest	(8-1/4, 7-1/4)	± 3/4"
I. One arm forward	(8-1/2, 7-1/8)	± 1"
J. Both arms forward	(8-3/4, 7-1/2)	± 7/8"
K. Holding to seat back	(7-7/8, 8-1/2)	± 3/4"

TABLE 111 - 8

Displacement of Body CG by Anterior Movements

Body Position	Location of Av. C. G.	Horizontal & Vertical Range For Subjects
A. Body standing straight	(4, 5-7/8)	± 7/8"
B. Head forward	(4-3/8, 5-5/8)	± 7/8"
C. Both arms extended forward	(5-1/4, 7)	± 3/4"
D. Head and trunk forward	(5-1/2, 4)	± 1-1/2"
E. Both legs straight forward	(9, 11)	± 1-1/4"
F. All body parts in maximum anterior position	(12, 10-3/4)	± 1-1/2"

TABLE 111 - 9

Displacement of Body CG by Posterior Movements

Body Position	Location of Av. C. G.	Horizontal & Vertical Range For Subjects
A. Standing, body straight	(5-1/4, 6)	± 1-1/8"
B. Head back	(5-1/2, 5-3/4)	± 1"
C. Arms back	(5-3/4, 6-1/4)	± 1"
D. Head & trunk back	(7-1/4, 5-1/8)	± 1-1/4"
E. Legs back	(6-7/8, 7-7/8)	± 1"
F. All body parts in maximum posterior position	(9-5/8, 6-1/8)	± 1-1/8"

TABLE 111 - 10

Displacement of Body CG by Lateral Movements

Body Position	Location of Av. C. G.	Horizontal & Vertical Range For Subjects
A. Standing, body straight	(0, 5-7/8)	± 7/8"
B. Head flexed to side	(1/2, 5-3/4)	± 3/4"
C. One arm extended laterally	(1/2, 6-3/8)	± 5/8"
D. One arm extended across chest	(3/8, 6-1/4)	± 3/4"
E. Head and trunk in lateral flexion	(1-3/4, 5-1/4)	± 3/4"
F. One leg abducted	(1-1/2, 6-3/4)	± 3/4"
G. Maximum lateral movement of both legs	(1-7/8, 6-5/8)	± 3/4"
H. All body parts moved laterally	(4-5/8, 7-1/4)	± 1-3/8"

TABLE 111 - 11

Displacement of Body CG by Cephalad Movements

Body Position	Location of Av. C. G.	Horizontal & Vertical Range For Subjects
A. Body standing straight	(5, 5-7/8)	± 7/8"
B. Both arms extended over head	(5-5/8, 8-1/8)	± 3/4"
C. Both legs in maximum position toward head	(10-3/8, 15)	± 1-1/2"
D. All body parts in maximum cephalad position	(11-1/8, 17-5/8)	± 1-5/8"

TABLE 111 - 12

Displacement of Body CG by Caudad Movements

Body Position	Location of Av. C. G.	Horizontal & Vertical Range For Subjects
A. Body standing straight	(0, + 5-7/8)	± 7/8"
B. Trunk and head in maximum flexion toward feet	(7-7/8, − 3/8)	± 3-3/8"
C. Trunk, head and arms in maximum position toward feet	(10-3/8, − 4-3/8)	± 1-7/8"

TABLE 111 - 13

Displacement of CG by Abduction of Arms and Legs

Body Position	Location of Av. C. G.	Vertical Range For Subjects
A. Standing, body straight	(0, 5-7/8)	± 7/8"
B. Both arms abducted	(0, 7-1/16)	± 5/8"
C. Both legs abducted	(0, 6-7/8)	± 3/4"
D. Both legs and both arms abducted	(0, 8-1/4)	± 3/4"

TABLE 111 - 14

Displacement of Body CG by Abduction of Arms and Legs as Measured from Floor Level

Body Position	Location of Av. C. G.	Vertical Range For Subjects
A. Body standing straight	(0, 38-1/4)	± 1-1/2"
B. Standing, both arms abducted	(0, 39-3/4)	± 1-1/2"
C. Standing, both legs abducted	(0, 36-1/4)	± 2-1/4"
D. Both arms and both legs abducted	(0, 37-5/8)	± 2-1/8"

TABLE 111 - 15

Displacement of CG by 20 lb. Back Pack (CG of Pack 18-5/8 Inches Above Ischium, 6 Inches Back) in Sitting and Standing Positions

Body Position	Location of Av. C. G.	Horizontal & Vertical Range For Subjects
A. Sitting without pack	(8-7/8, 9-5/8)	± 1-1/8"
B. Sitting with pack	(7-1/2, 10-1/2)	± 1-1/8"
C. Standing without pack	(5, 5-7/8)	± 7/8"
D. Standing with pack	(3-3/4, 7-1/4)	± 7/8"

112. Anon. Pre-loading System Adjusts Torsion-suspended Seat. Design News, Volume 10, No. 15, August 1, 1955, pp. 26-27.

This article describes a new seat designed to isolate shock and vibration so as to avoid back and kidney damage to truck, bus, and tractor drivers. Two rubber blocks used as torsion springs are preloaded according to the weight of the person occupying the seat, the adjustment ranging from 100 to 275 pounds. The seat has a natural frequency below that of the vehicle, a design feature that prevents vibrations from reaching the driver. The seat can be adjusted for depth, height, back angle, cruising angle, and for nine positions of fore and aft movement. The frame is tubular steel and the cushions are foam rubber. The seat is estimated to accommodate 99% of all drivers. The Bostrom Company of Milwaukee, designed the seat, which is designated the "Level Ride 80".

The article is two pages long including four figures. Three figures are presented as part of the annotation.

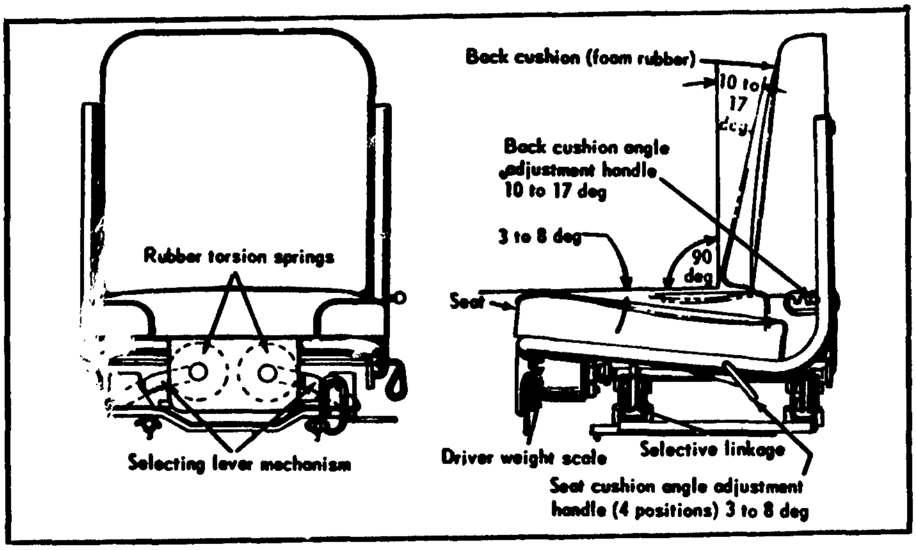


FIGURE 112 - 1

Tubular Seat Frame
Welded to a channel section bed plate which carries the rubber torsion spring and linkage mechanism. Four mountings provide for the attachment of the assembly to standard slide rails. Back cushion angle adjustment handles are spring tensioned in slots at either side of the base. For the convenience of the driver, most adjustment controls are located on the left side.

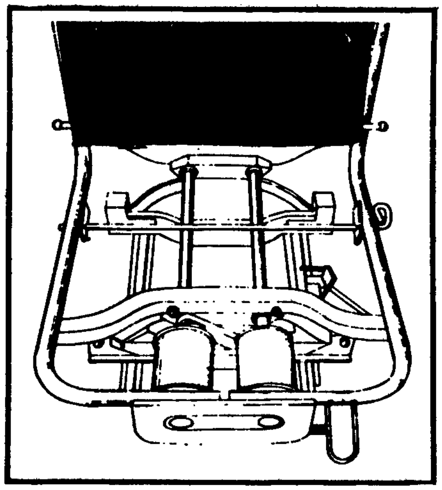


FIGURE 112 - 2

With Seat Cushion Removed
The entire suspension system is revealed. Electronic ride measurements show this seat to be five times more effective in absorbing shock than the best conventional seat.

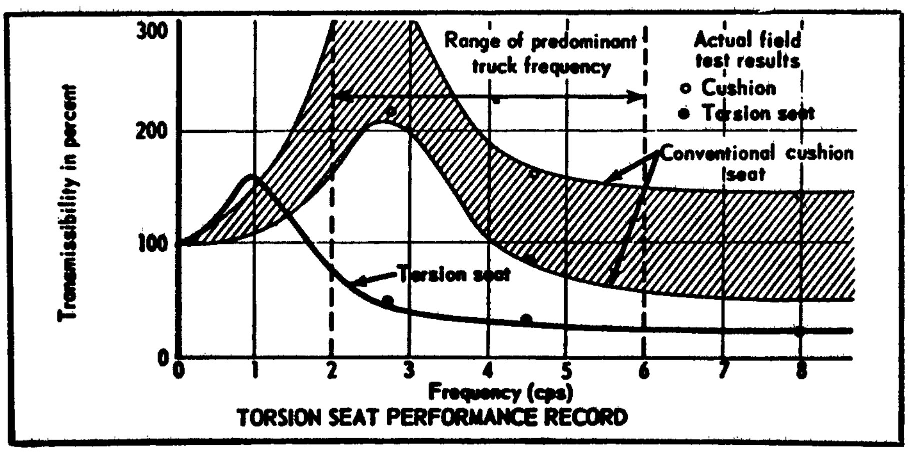


FIGURE 112 - 3

Measurements
Of shock frequency made under actual operating conditions show the torsion-suspended seat to be considerably more efficient in intercepting ride motion energy that can damage body organs.

113. Brown, R.W. and H.C. Dickinson. Criteria are Set for Riding Comfort Research; New Instruments Made. Society of Automotive Engineers Journal, Volume 37, No. 2, August 1935, pp. 20-23.

This article discusses the requirements which are the essential basis for the practical measurement of riding comfort. Various forms of instrumentation are presented, with photographs, and their utlization and calibration curves shown. The major problem has been to produce measuring instruments which are not strictly of a laboratory nature.

"After careful consideration of all pertinent information, the Riding Comfort Research Subcommittee (Society of Automotive Engineers) has arrived at the following essentials as a basis for the practical measurement of riding comfort.

"The measuring instrument should be actuated by the forces which occur between the occupant of the vehicle seat and the upholstery of the seat. Conceivably this might be accomplished by using a 'dummy observer' resembling a human being in shape and weight distribution, or by using some sort of indicator, such as a pneumatic cushion, between the subject and the upholstery.

"The instrument should make an integrated record of the accelerating forces and the total time of application of these forces, exclusive of the static forces.

"As an alternative, the instrument should record preferably the total number of times the accelerating force exceeds some predetermined limit.

"The instrument should be adjustable so that the relative effects of the forces of different periods and intensities can be taken into account in the system of interpolation, so that finally an integral result can be had which matches the average result obtained with a large number of observers.

"The record should be a single integral figure for any given length of road or length of time.

"The vertical forces on the seat and the pitching, or fore and aft forces, on the back should be recorded separately, probably on separate instruments. Transverse forces might be measured, if desired, by the same sort of instrument used for the back, but this might require some special type of car seat since there is no fixed position from which to start in the transverse direction.

"The instrument or instruments must be so designed and constructed as to be capable of calibration in terms of known fundamentals. Static calibrations will be acceptable provided they are fully substantiated by investigation of dynamic properties throughout the operating range.

"Compact, small-size, light-weight instruments are desired, suitable for use in motor vehicles. Various types, if electrically operated, should be suitable for operation on a 6-volt conventional motor-vehicle battery.

"Provision should be included for simple field checking of the zero or other known point on the scale.

"The instrument should be of such simple design and construction as to permit its usage by one operator in road service."

The article includes seven figures and two bibliographic references.

114. Darcus, H.D. and A.G.M. Weddell. Some Anatomical and Physiological Principles Concerned in the Design of Seats for Naval War-Weapons. British Medical Bulletin, Volume 5, No. 1, 1947, pp. 31-37.

"This paper describes the desiderata for, and the design of, an adjustable seat for use in naval war-weapons. Although this seat was specifically designed for use with sighting-apparatus, the principle of maintaining stability by the use of counterpressure between the feet and the back-rest is so important that similar seats are to be tried experimentally in other situations aboard ship."

"The chief requirements of an ideal seat for use with naval war-weapons are as follows:

a. It must accommodate at least 90% of individuals of different body-dimensions in the most efficient position.
b. It must permit the attainment and maintenance of the maximum degree of body-stabilization.
c. It must allow the operator to maintain a sitting-position for periods of duty up to four hours without undue discomfort or fatigue, and must allow for an alert and a relaxed position.
d. It must combine lightness with mechanical efficiency, withstand very severe usage, and be weatherproof."

It is stressed that the seat should be designed to maintain more pressure on the ischial tuberosities than on the surrounding tissues; the shaped or "ploughman" seat with a perineal elevation (or pommel) goes against this principle. A flat but padded surface is considered best.

"It must be noted, however, that there is no one correct posture for all individuals...because the normal range is large. Thus the design of the seat must be such that it imposes on the operator the best average position."

The report is six pages long including two figures and a bibliography of 24 items. There are no tables. No mention is made of the seat reference point.

115. Hertzberg, H.T.E. and John W. Colgan. A Prone Position Bed for Pilots. Memorandum Report No. MCREXD-695-71D, Aero Medical Laboratory, Engineering Division, Headquarters Air Material Command, United States Air Force, 25 June 1948. (Armed Services Technical Information Agency No. ATI-34088.)

This report describes "the development of a prone position bed for pilots, and the results of comfort tests thereof.

"The subject bed consists of specially-shaped sides to which a length of nylon netting is affixed. Special controls, foot rests, net tension adjusting cams for abdominal support, chin rest and head support are required as adjuncts to the bed proper... . Although all features of the bed have been evolved by intensive development through various forms, in general only the present end product is described in Appendix I, to which detailed working drawings are attached.

"Comfort tests of the bed were conducted with a series of 19 adult males, of which 9 were laboratory personnel and 10 were bomber and fighter pilots. In stature the series ranged from 63.8 inches to 74.2 inches, in weight from 127 lbs. to 220 lbs., thus representing over 95% of USAF personnel in both stature and weight... .

"Eighteen subjects lay on the prone position bed for eight consecutive hours each, or longer, and one subject lay four hours. After formal tests were completed, two members of the test team lay on the bed for twelve hours each.

"The bed was adjusted to each subject for utmost comfort. The major adjustments were for stature, for abdominal support and for arm position on the controls... . Changes in length of bed or in net tension by means of the cams were made throughout the eight-hour period as desired by the subject. Each occupant was permitted to move on the bed in any way that would be possible in an actual cockpit.

"It was found that boredom, rather than fatigue or discomfort, was the chief complaint of all subjects. To allay boredom, moving pictures were shown to each man for at least four hours. Certain measurements were also made in the intervals between pictures.

"Conventional flying suits were available, and many subjects used them during the tests. It was found that breast pockets and the numerous zippers, especially those in the knee and shin region, were troublesome in causing pressure areas.

"Food for the subjects was prepared from a stock of "E" rations. It was found that eating was entirely feasible and satisfactory under the conditions of the test.

"A number of pilots upon conclusion of their runs stated that they felt no discomfort at all, and volunteered their opinion that they could have continued for several hours more, particularly if they had had something to do.

"It is emphasized that the bed described herein has so far been tested only under static conditions, and that detailed flight tests must be made before the total problem can be considered solved."

The pilots testing the bed reported it to be more comfortable for long periods than present conventional airplane seats.

"A high-performance fighter airplane should be modified for the installation of the prone position assembly for final test and evaluation."

The report is 32 pages long and includes three tables, seven figures and seven appendices. The bibliography includes 21 items.

Editor's note: For the purposes described in the year 1948, the bed described here was strictly a laboratory mock-up. Since then there has been considerable further development of the jaw rest, the foot rests, and the adjustable cams into finished items. Details of their construction, however, have not yet been published, and are not otherwise available at this time (September 1955). A report is planned for the future to bring design developments and the results of flight tests in B-17 and F-80 aircraft up to date.

116. Hick, W.E. Safer Seating. Aeronautics (Great Britain), Volume 24, May 1951, pp. 36-37.

This article discusses aircraft accidents with particular reference to seating. Seating, harnesses and direction of facing are considered in relation to "crash-energy" (direction of crash) absorption. It is noted that "there is much more evidence that the deceleration of any part reasonably far from the point of impact may be quite moderate."

After discussing what happens in a crash, the causes of fatal injuries are discussed. A forward-facing passenger with only a lap belt tends to jack-knife with possible spine injuries, or head injuries due to contact with equipment or his own knees. It is noted that a 1.02 meter distance between seats (rear edge of base to rear edge of base is shown) is "necessary to ensure that the passenger's head clears the back of the seat in front of him. The body dimensions are taken from data relating to male service personnel, and the allowance made for above-average stature covers 98 per cent of such people - or, say, about 99 per cent of a typical sample of men and women passengers." No source or data are provided for this statement. It is noted that "the path of the head, in swinging forward and down, is not a circular arc about the hip joints, but is a spiral curling inwards...due to flexure of the spine" and "no allowance has been made for the lower leg swinging up to the horizontal about the knee joint." Tables would alter seat spacing problems. They must be folded out of the way and secured before the crash or a complete harness must be provided.

In contrast, the backward-facing seat requires the lap belt only to prevent the passenger being thrown out sideways, and lower-leg injury from the feet slipping under the seat can easily be eliminated. This deceleration of the head when it is not resting on the headrest at the time of the crash is considered to be a crucial problem. Whereas the headrest should be padded to counter the head movement due to the passenger's tendency to sit up rather than to relax against the seat headrest, it is noted that "we seem forced to conclude that the backward-facing seat requires, to realize its full worth, some simple shoulder or body harness; with this, we need only design for a few inches of 'give' in the head rest."

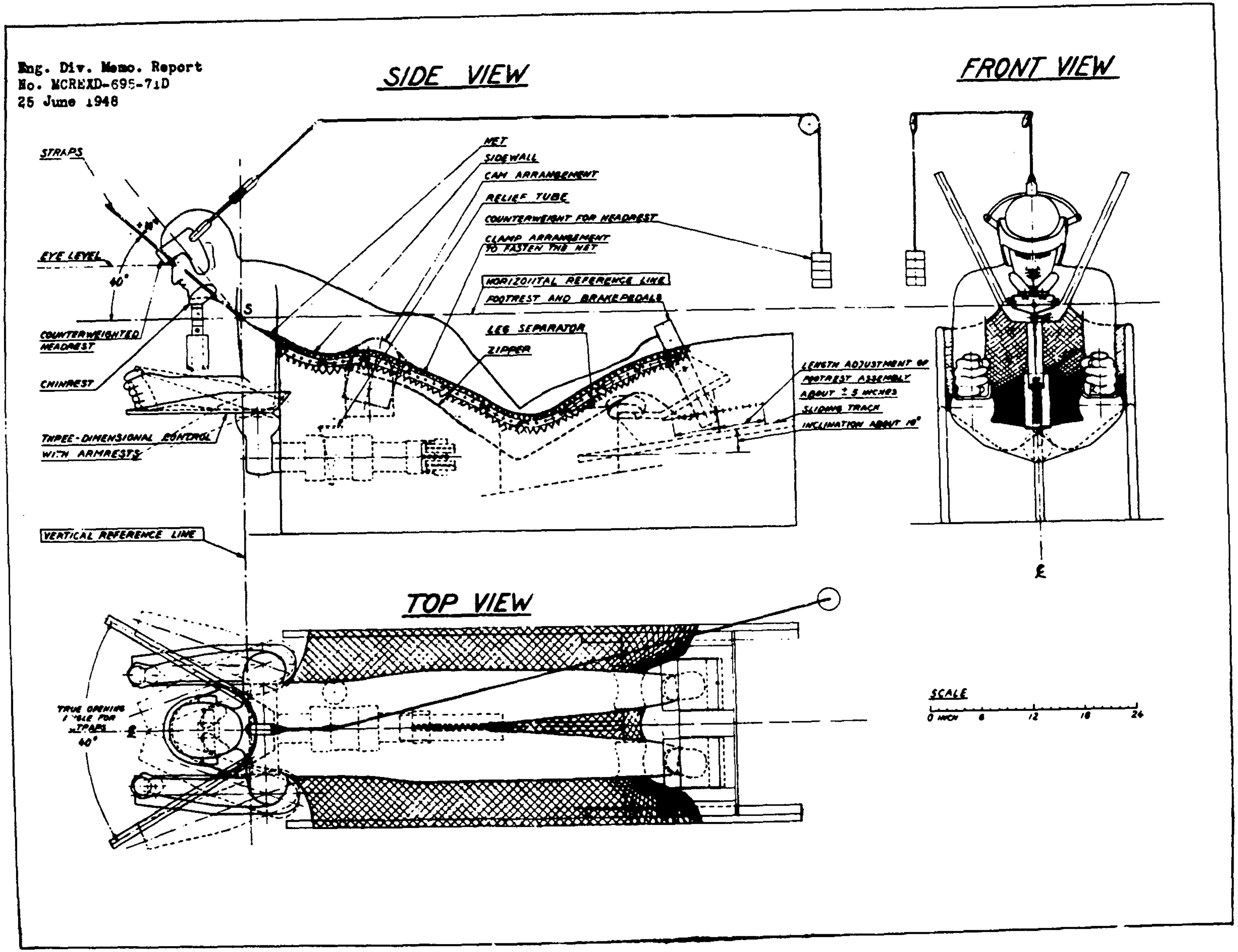
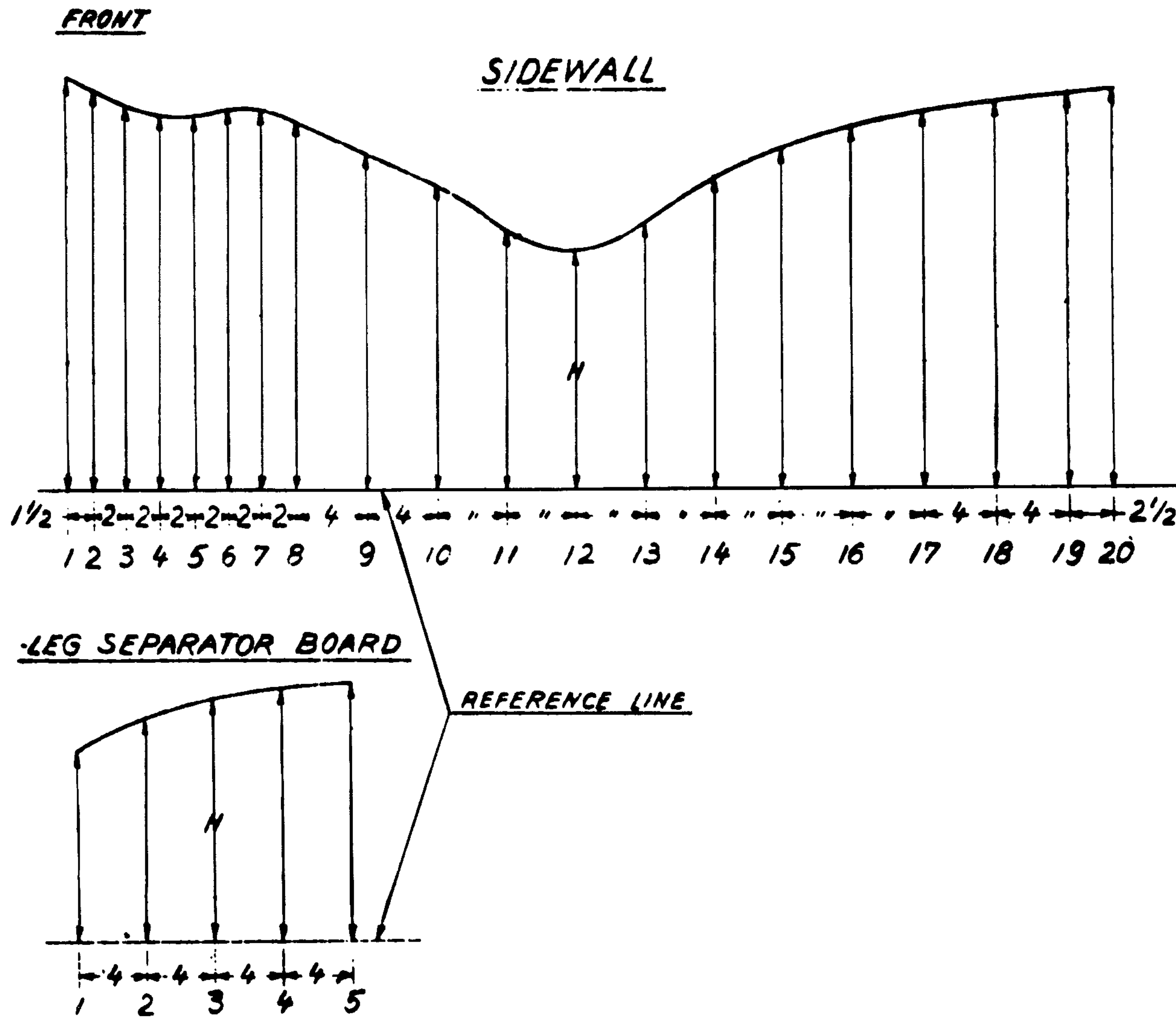


FIGURE 115 - 1

Prone Position Bed



STA.	HEIGHT H SIDE WALL	HEIGHT H LEG SEPARAT.
1	22 7/8	10 1/2
2	22 3/16	12 1/2
3	21 5/16	13 1/2
4	20 3/4	14
5	20 3/4	14 3/8
6	21	
7	21	
8	20 3/8	
9	18 5/8	
10	16 7/8	
11	14 1/4	
12	13 1/4	
13	14 5/8	
14	17 1/4	
15	18 7/8	
16	20	
17	20 7/8	
18	21 1/2	
19	21 7/8	
20	22 1/8	

FIGURE 115 - 2

Measurements for Sidewall and Centerpiece of the Bed

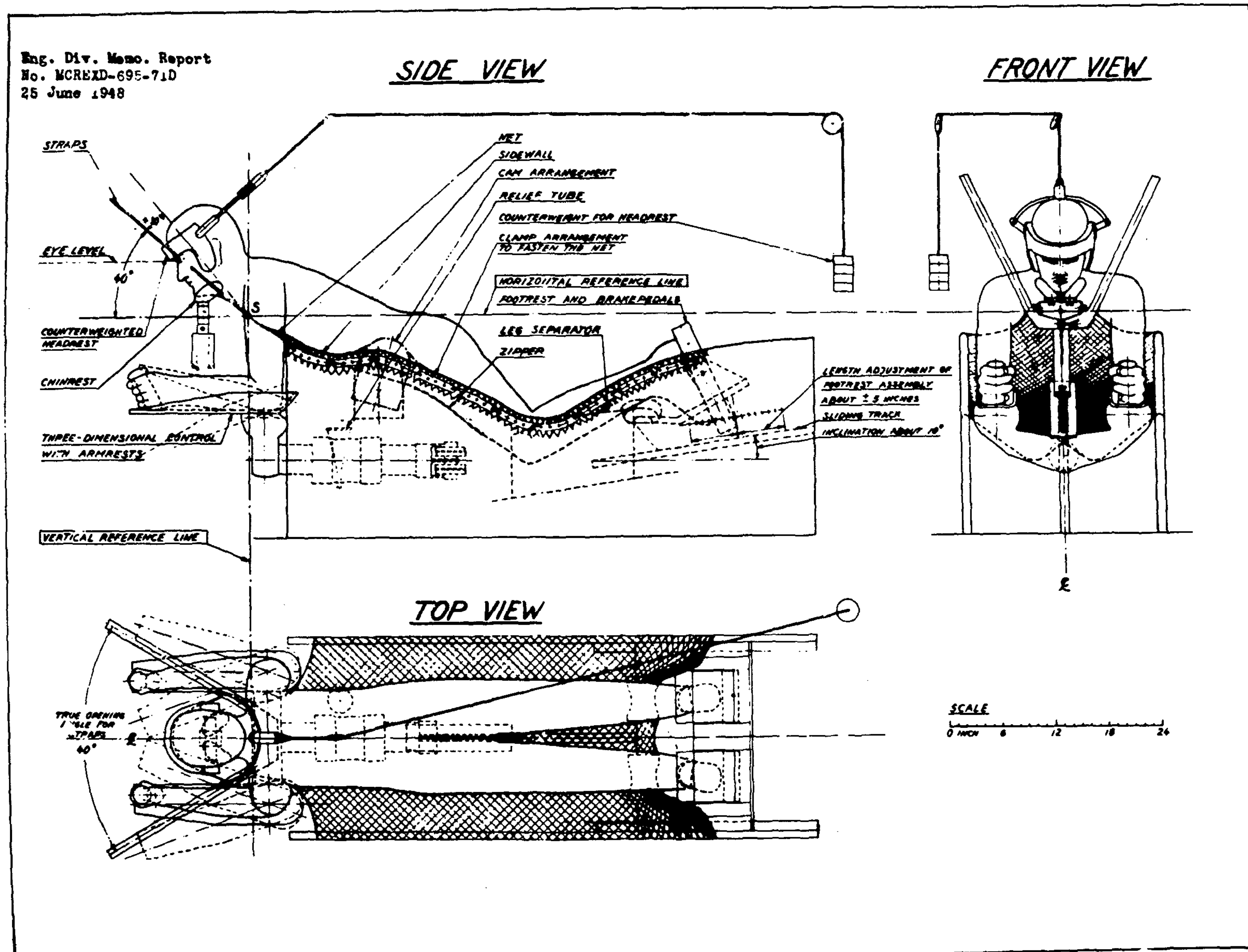
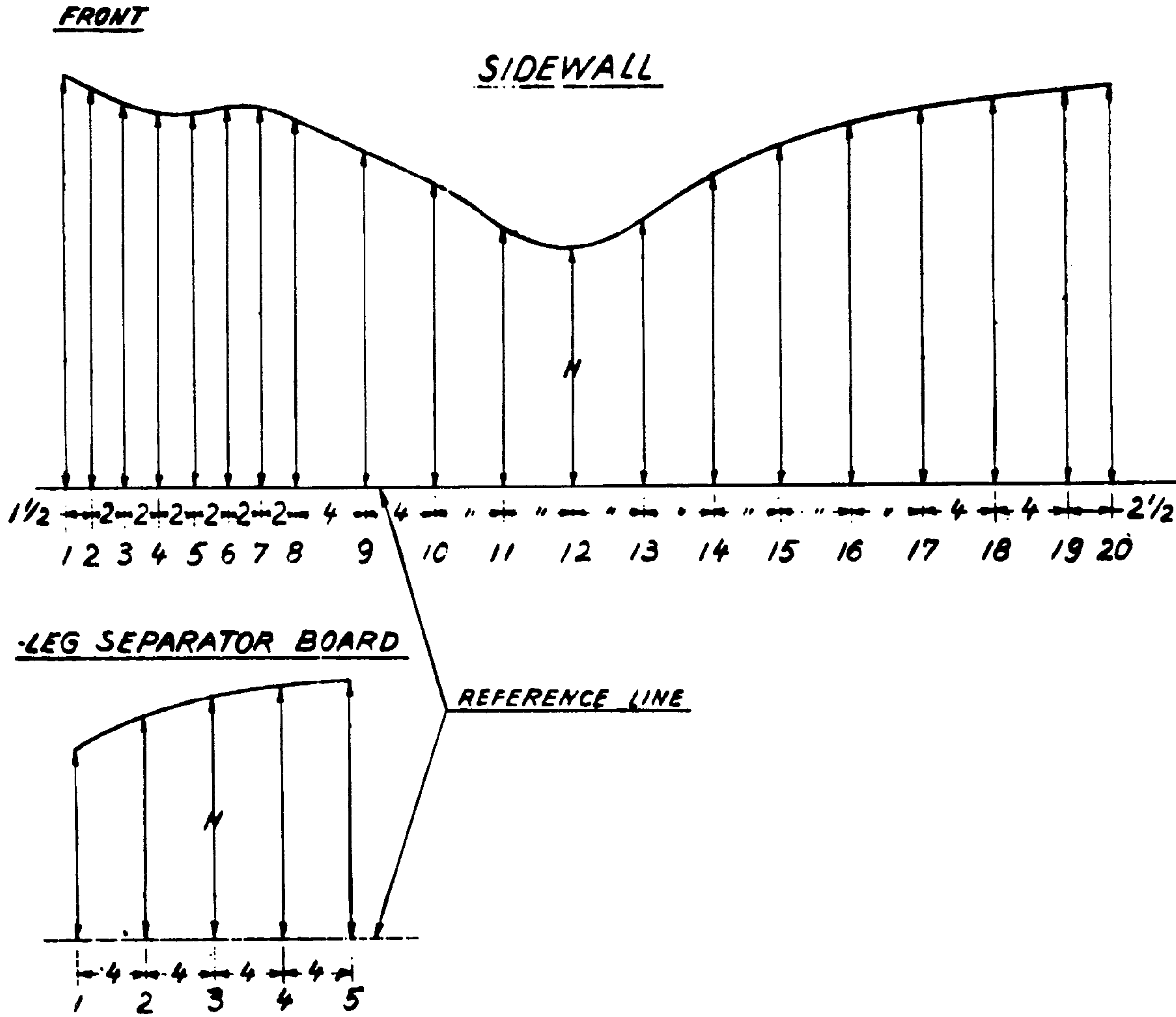


FIGURE 115 - 1

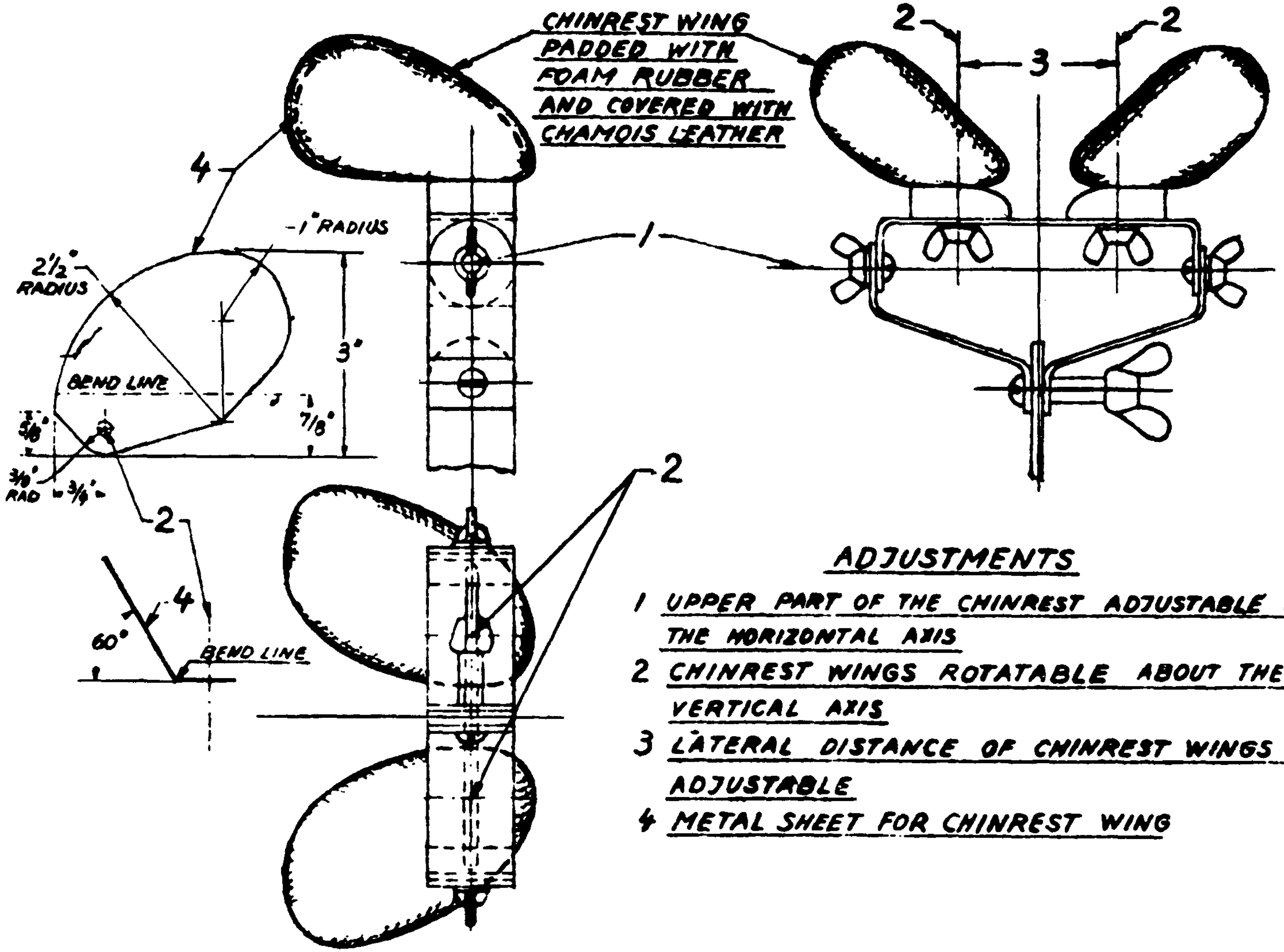
Prone Position Bed



STA.	HEIGHT H SIDE WALL	HEIGHT H LEG SEPARAT.
1	22 7/8	10 1/2
2	22 3/16	12 1/2
3	21 5/16	13 1/2
4	20 3/4	14
5	20 3/4	14 3/8
6	21	
7	21	
8	20 3/8	
9	18 5/8	
10	16 7/8	
11	14 1/4	
12	13 1/4	
13	14 5/8	
14	17 1/4	
15	18 7/8	
16	20	
17	20 7/8	
18	21 1/2	
19	21 7/8	
20	22 1/8	

FIGURE 115 - 2

Measurements for Sidewall and Centerpiece of the Bed



ADJUSTMENTS

1 UPPER PART OF THE CHINREST ADJUSTABLE ABOUT THE HORIZONTAL AXIS
2 CHINREST WINGS ROTATABLE ABOUT THE VERTICAL AXIS
3 LATERAL DISTANCE OF CHINREST WINGS ADJUSTABLE
4 METAL SHEET FOR CHINREST WING

FIGURE 115 - 3

Chinrest

It is noted that backward-facing seats have not been utilized primarily because airline operators consider that this style of facing will be unacceptable to passengers and that such seating will emphasize flying risks.

The article includes one figure and no bibliographic references.

117. Hooton, Earnest A. A Survey in Seating. Gardner, Massachusetts: Heywood-Wakefield Company, 1945.

This study represents a detailed analysis of human dimensions for railway coach seating. Eight measurements were taken on approximately 3900 persons who were selected with an effort (1) to prevent any particular age group from becoming greatly superior numerically to the other age groups, (2) to obtain an equal number of males and females, and (3) to obtain people from all economic and social levels. The measurements were taken by means of a special measuring chair manufactured by the Heywood-Wakefield Company and calibrated to an accuracy of one-eight of an inch; and by means of a weighing scale, also equipped with a measuring rod for taking stature. More detailed descriptions of the measuring techniques, of the sample (population), and of the statistics are presented. The age ranges were: males 17-89 years, females 17-84 years and the total group 17-89 years. The age means were: males 38.45 years, females 35.55 years, total group 37.00 years.

The subjects were measured in normal clothing, "without a topcoat," in railroad stations in Boston and Chicago.

"The measurements were obtained as follows:

1. "The seat was raised until the individual's feet were not in firm contact with the floor. The lower legs were allowed to hang straight down. The seat-length rod was then pulled out until it touched the uppermost part of the lower leg behind the knee.

2. "The seat was slowly lowered until the individual's feet rested firmly on the floor. The firmness was determined by questioning the individual, and by grasping one of his feet and attempting to move it. The seat was never lowered so far that the popliteal area (the lower portion of the upper leg just behind the knee) was not in contact with the seat surface.

3. "The individual was asked to place his forearm on (and parallel with) the arm-rest, which was raised or lowered until the individual's shoulders were level and the angle between his upper arm and forearm was approximately 90°. This position, by the way, was described by the majority as comfortable.

4. "The measurements of seat length (1), seat height (2), and elbow height (3), were then read aloud by the measurer to the recorder, who wrote them down and repeated them so as to avoid possible errors.

5. "The hip breadth was then measured by bringing the arms of the calibrated hip-breadth rod together until they touched the portions of the buttocks or upper thighs expanding to the maximum "spread." Care was taken not to include objects in pockets, and enough pressure was exerted to compress the clothing if it was loose. The measurement was then read aloud as before and repeated by the recorder.

6. "The back height was then measured by pulling up the back-height rod and placing the crutch-like end of its transverse arm (at right angles to the rod and extending forward towards the back of the subject's head) at the point of junction between the head and neck. This point, roughly called the "nape of the neck," is actually the region of the first and second cervical vertebrae, and is easily located in most people, even in women wearing long hair. During this measurement the subject was, if necessary, asked to sit erect. The measurement was read aloud as usual.

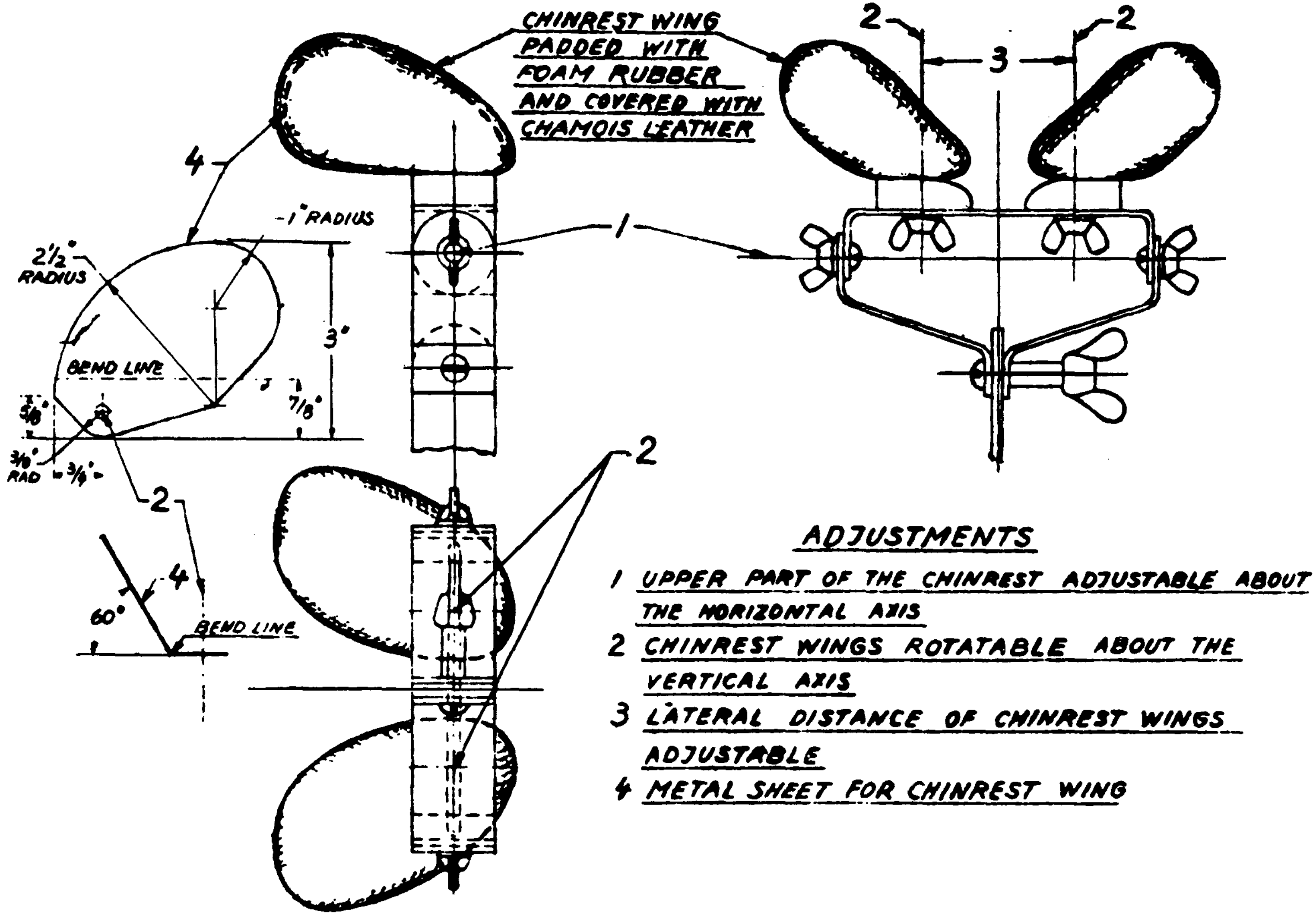


FIGURE 115 - 3

Chinrest

It is noted that backward-facing seats have not been utilized primarily because airline operators consider that this style of facing will be unacceptable to passengers and that such seating will emphasize flying risks.

The article includes one figure and no bibliographic references.

117. Hooton, Earnest A. A Survey in Seating. Gardner, Massachusetts: Heywood-Wakefield Company, 1945.

This study represents a detailed analysis of human dimensions for railway coach seating. Eight measurements were taken on approximately 3900 persons who were selected with an effort (1) to prevent any particular age group from becoming greatly superior numerically to the other age groups, (2) to obtain an equal number of males and females, and (3) to obtain people from all economic and social levels. The measurements were taken by means of a special measuring chair manufactured by the Heywood-Wakefield Company and calibrated to an accuracy of one-eight of an inch; and by means of a weighing scale, also equipped with a measuring rod for taking stature. More detailed descriptions of the measuring techniques, of the sample (population), and of the statistics are presented. The age ranges were: males 17-89 years, females 17-84 years and the total group 17-89 years. The age means were: males 38.45 years, females 35.55 years, total group 37.00 years.

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3. "The individual was asked to place his forearm on (and parallel with) the arm-rest, which was raised or lowered until the individual's shoulders were level and the angle between his upper arm and forearm was approximately 90°. This position, by the way, was described by the majority as comfortable.

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7. "The shoulder breadth was taken by bringing the arms of the shoulder-breadth rod together until they touched the individual's deltoid muscles (the point of maximum lateral expansion). If the individual tended to hold his arms out from his body, this position was corrected by requiring him to keep his arms against his body. The measurement was read aloud as usual.

8. "The individual was asked to step onto the scales, where his height was recorded (within 1/4 inch) and his weight (to the nearest pound).

"In addition to these measurements, the following information was obtained:

1. Age
2. Birthplace
3. Type of shoe heel (for females only)
4. Whether or not the shoes were habitually removed when travelling by train (for females only)."

Intercorrelations are presented for the various measurements and some material relative to curvature of the spine in sitting and standing. Important factors not considered in the author's survey are (1) pitch of seat and back, (2) shape of seat and back, and (3) adjustability of seat and back.

The tentative recommendations of this study (more fully discussed in the report) are:

1. Seat Length - 20 inches
2. Back Height - 28 inches
3. Elbow Height - 8.5 inches
4. Hip Breadth - 19 inches*
5. Shoulder Breadth - 19 inches*
6. Seat Height - 16.9 inches.

The 101 pages of the report include 11 tables of anthropometric and other data, 22 scattergrams of anthropometric dimension correlations, and photographs of the test chair and selected sand molds of the body patterns.

Additional reference: Hooton's Chair. Life Magazine, February 11, 1946, pp. 33-36.

*"Note. The recommendations of 19 inches for hip breadth and shoulder breadth are not based upon optimum conditions, but upon the restrictions of maximum over-all seat breadth of 44 inches, as described to us. These recommendations are then a compromise. Nevertheless, the dimensions thus recommended should be adequate for more than 85% of the travelling public."

118. Lay, W.E. and L.C. Fisher (University of Michigan). Riding Comfort and Cushions. Society of Automotive Engineers Journal (Transactions), Volume 47, No. 5, 1940, pp. 482-496.

"This paper reports work begun in 1935 at the instigation of the Murray Corp. of America. Methods used in studying the relations between the automobile seat cushion and its function in transporting passengers with greater comfort and less fatigue are described.

"Constructed for this purpose was a piece of apparatus called the Universal Test Seat, whose dimensions were completely adjustable with arrangements to vary the distribution of the supporting pressure in any manner which seemed most comfortable to the passenger.

"The authors describe tests made by use of this apparatus, present summaries of some of the results recorded and conclude that, to give the passenger the maximum comfort and least fatigue, the following mechanical objectives should be attained by the cushion:

TABLE 117 - 1

American Adult Body Measurements Relative to Dimensions of Seats

	Number Measured	Range	Percentiles 5th	50th	95th
Weight(pounds)					
Males	1959	100 - 309	132.3	166.7	217.5
Females	1908	70 - 309	103.7	133.1	179.3
Total Group	3867	70 - 309	110.0	152.8	207.6
Stature					
Males	1959	59 - 80	64.5	69.0	73.8
Females	1908	55 - 73	60.8	64.9	69.1
Total Group	3867	55 - 80	61.6	66.9	72.9
Seat Length					
Males	1959	15.4 - 23.1	17.4	18.9	20.8
Females	1908	15.5 - 22.2	16.8	18.2	20.0
Total Group	3867	15.4 - 23.1	17.0	18.6	20.4
Seat Height					
Males	1959	15.6 - 22.0	17.6	19.0	20.6
Females	1908	15.4 - 20.6	16.7	18.1	19.5
Total Group	3867	15.4 - 22.0	16.9	18.5	20.2
Back Height					
Males	1959	23.6 - 33.1	26.6	28.6	30.6
Females	1908	22.1 - 30.1	24.9	26.7	28.6
Total Group	3867	22.1 - 33.1	25.3	27.6	30.2
Elbow Height					
Males	1959	6.7 - 12.0	8.1	9.6	11.1
Females	1908	7.0 - 12.0	8.4	9.7	11.1
Total Group	3867	6.7 - 12.0	8.1	9.6	11.1
Hip Breadth					
Males	1959	12.0 - 21.3	13.7	15.3	17.4
Females	1908	12.1 - 20.6	13.1	14.6	17.2
Total Group	3867	12.0 - 21.3	13.3	15.0	17.3
Shoulder Breadth					
Males	1959	14.5 - 22.4	16.4	17.6	19.2
Females	1908	12.7 - 21.7	14.4	15.7	17.6
Total Group	3867	12.7 - 22.4	14.7	16.9	18.8

Note: Dimensions in inches, unless otherwise noted.

1. To support the passenger over a large area to get the smallest unit pressure on the flesh;
2. To avoid variations in pressure from point to point over the supported area except those variations dictated by actual variations in the body of the passenger. (To obtain the surface contour and pressure distribution on the loaded cushion that is considered by the average passenger to be the most comfortable.)

"By extending their analysis of the conditions required for static comfort, the authors believe that the objectives to be attained for dynamic comfort are:

1. To avoid large changes in pressure or forces acting on the body of the passenger with respect to time;
2. Especially to avoid high rates of change, with respect to time, of either the values or direction of pressures or forces acting on the human body."

The article is 14 pages long and contains 26 figures. Six of the figures are included with the annotation.

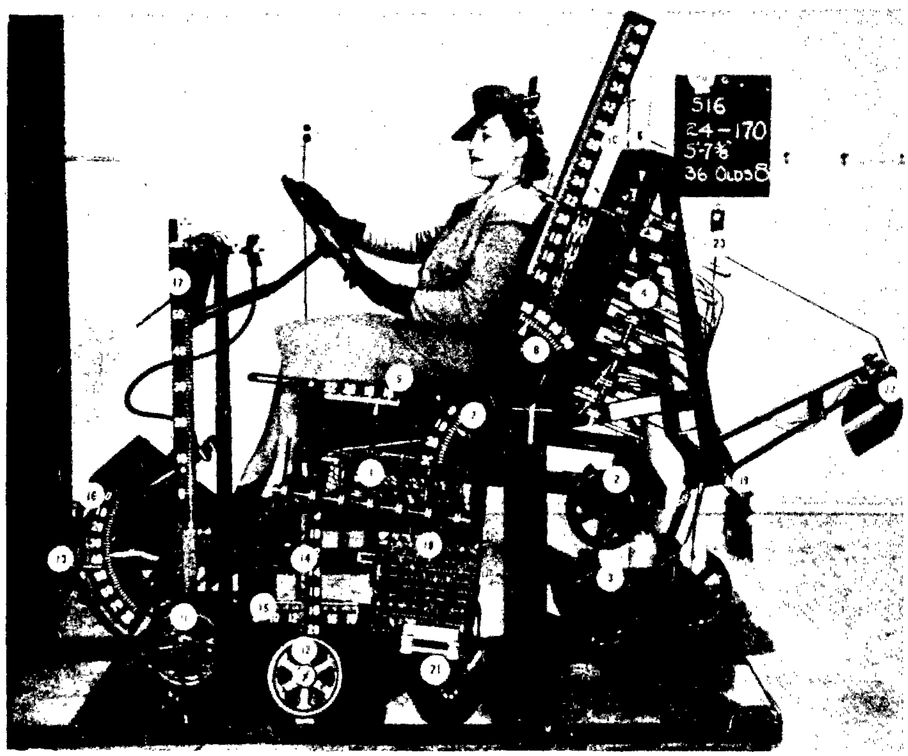
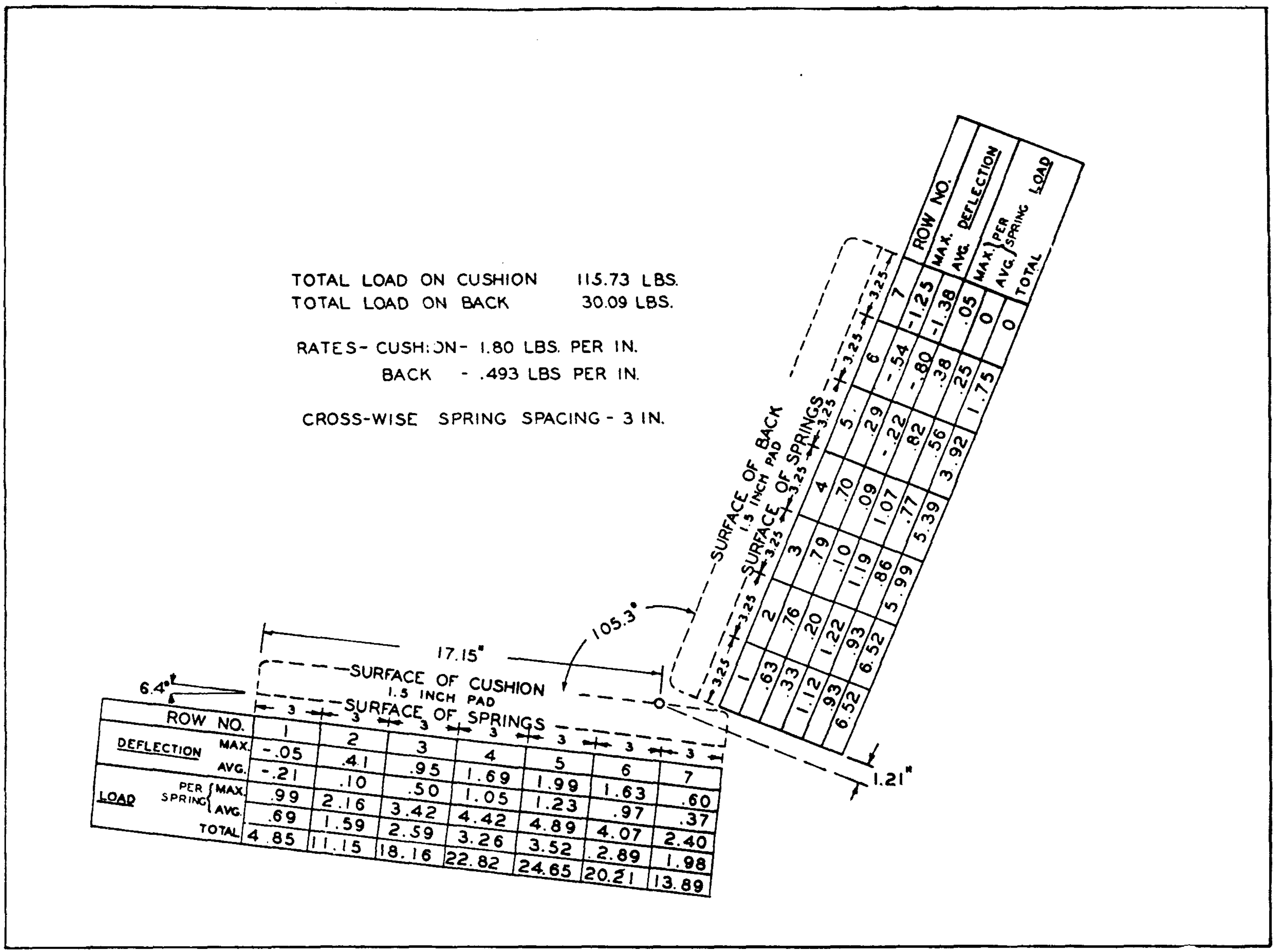


FIGURE 118 - 1

Universal Test Seat - Side View



Cushion:

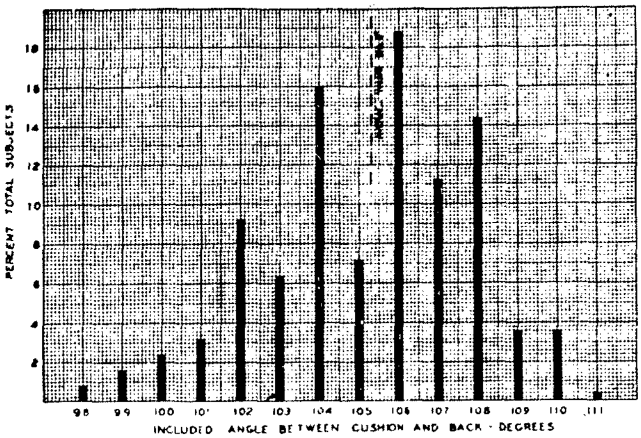
ROW NO.		1	2	3	4	5	6	7
DEFLECTION	MAX.	-.05	.41	.95	1.69	1.99	1.63	.60
	AVG.	-.21	.10	.50	1.05	1.23	.97	.37
LOAD PER SPRING	MAX.	.99	2.16	3.42	4.42	4.89	4.07	2.40
	AVG.	.69	1.59	2.59	3.26	3.52	2.89	1.98
	TOTAL	4.85	11.15	18.16	22.82	24.65	20.21	13.89

Back:

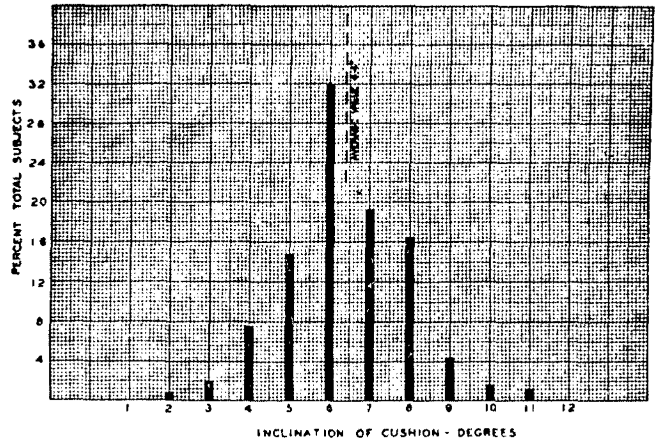
ROW NO.		1	2	3	4	5	6	7
DEFLECTION	MAX.	.63	.76	.79	.70	.29	-.54	-1.25
	AVG.	.33	.20	.10	.09	-.22	-.80	-1.38
LOAD PER SPRING	MAX.	1.12	1.22	1.19	1.07	.82	.38	.05
	AVG.	.93	.93	.86	.77	.56	.25	0
	TOTAL	6.52	6.52	5.99	5.39	3.92	1.75	0

FIGURE 118 - 2

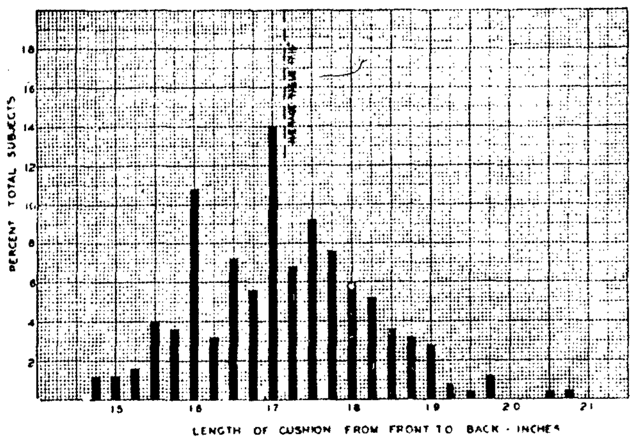
Location of Springs in Cushion and Back - Load-deflection Data for each Crosswise Row of Springs



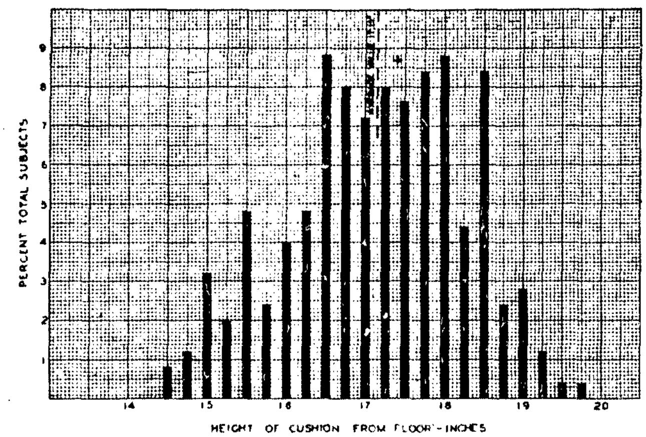
■ FIG. 118-3 – Per cent of total subjects selecting various values for
INCLUDED ANGLE BETWEEN CUSHION AND BACK



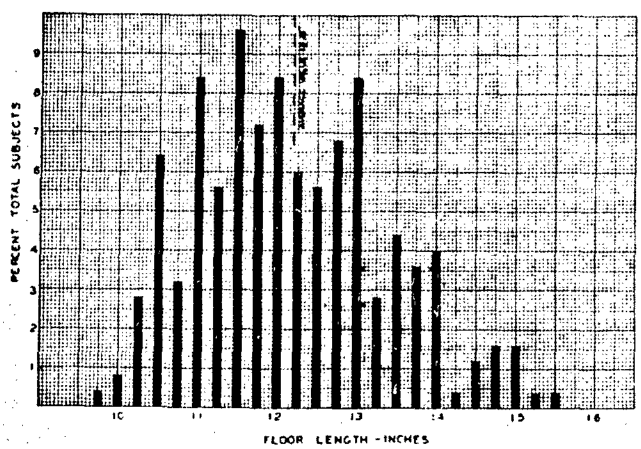
■ FIG. 118-4 – Per cent of total subjects selecting various values for
CUSHION INCLINATION



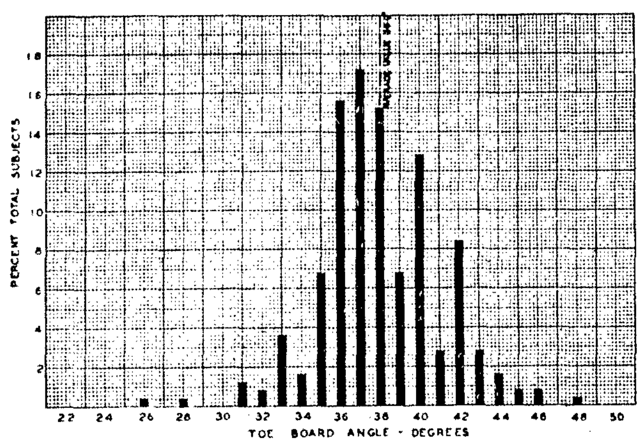
■ FIG. 118-5 – Per cent of total subjects selecting various values for
CUSHION LENGTH



■ FIG. 118-6 – Per cent of total subjects selecting various values for
CUSHION HEIGHT



■ FIG. 118-7 – Per cent of total subjects selecting various values for
FLOOR LENGTH



■ FIG. 118-8 – Per cent of total subjects selecting various values for
TOE-BOARD ANGLE

SYMBOL	NAME	WEIGHT IN POUNDS	PERCENT OF TOTAL WEIGHT
X O	HEAD	10.7	6.9
X R	TRUNK-NECK	70.7	46.1
X 1	UPPER ARMS	10.1	6.6
X 3	LOWER ARMS	6.4	4.2
X 5	HANDS	2.6	1.7
X 6	UPPER LEGS	33.0	21.5
X 8	LOWER LEGS	14.7	9.6
X 10	FEET	5.2	3.4
X S	TOTAL (WHOLE BODY)	153.4	100.00

FIGURE 118 - 9

Distribution of Weight in an Average Man

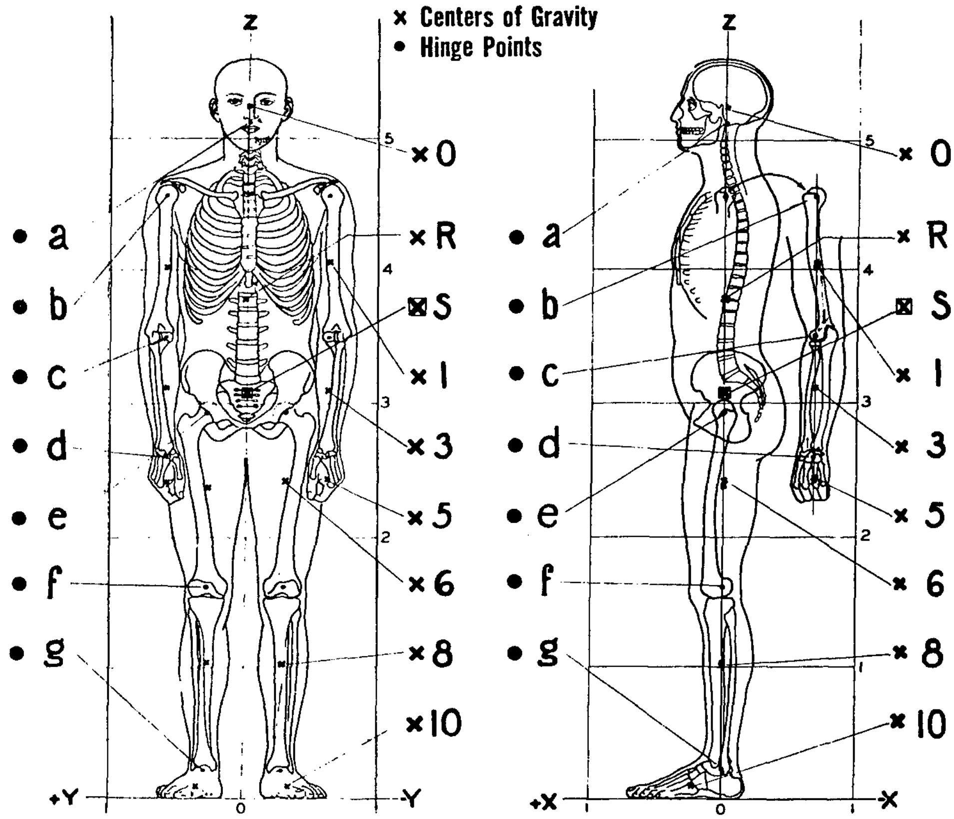


FIGURE 118 - 10

Location of Hinge Points and Centers of Gravity of the Human Body

LOCATION OF HINGE POINTS AND CENTERS OF GRAVITY OF THE HUMAN BODY							
SYMBOL	NAME	LOCATION ON FIGURE NO.					
		COORDINATES IN INCHES			COORDINATES IN PERCENT HEIGHT		
		X	Y	Z	X	Y	Z
	HINGE POINTS						
• a	BASE OF SKULL ON SPINE	0.0	0.0	61.58	0.0	0.0	91.23
• b	SHOULDER JOINT	0.0	±7.16	54.78	0.0	±10.66	81.16
• c	ELBOW	0.0	±7.16	41.99	0.0	±10.66	62.20
• d	WRIST	0.0	±7.16	31.19	0.0	±10.66	46.21
• e	HIP	0.0	±3.40	35.19	0.0	± 5.04	52.13
• f	KNEE	0.0	±3.40	19.19	0.0	± 5.04	28.44
• g	ANKLE	0.0	±3.40	2.60	0.0	± 5.04	3.85
	CENTERS OF GRAVITY						
× 0	HEAD	0.0	0.0	63.1	0.0	0.0	93.48
× R	TRUNK-NECK	0.0	0.0	48.0	0.0	0.0	71.09
× 1	UPPER ARM	0.0	± 7.16	48.42	0.0	± 10.66	71.74
× 3	LOWER ARM	0.0	± 7.16	37.34	0.0	± 10.66	55.33
× 5	HAND	0.0	± 7.16	29.11	0.0	± 10.66	43.13
× 6	UPPER LEG	0.0	± 3.40	28.67	0.0	± 5.04	42.48
× 8	LOWER LEG	0.0	± 3.40	12.28	0.0	± 5.04	18.19
× 10	FOOT	2.50	± 4.16	1.20	3.85	± 6.16	1.78
⊠ S	TOTAL (WHOLE BODY)			37.31			55.27

FIGURE 118 - 11

Location of Hinge Points and Centers of Gravity of the Human Body

119. Lippert, Stanley. Designing for Comfort in Aircraft Seats. Aeronautical Engineering Review, Volume 9, No. 2, (February) 1950.

In his article the author discusses seat design relative to comfort aspects and design procedures, based on literature surveys and tests under the jurisdiction of Douglas Aircraft Company, Inc. The article includes: (1) Dimensional data on several population groups; (2) Correct position in space for a passenger-type chair; (3) Desirable dynamic properties of seats in gusts and in steady-state vibrations; (4) A discussion of shock mounts; (5) A brief discussion on ventilating properties of cushions.

Using anthropometric data from Randall (Randall, F.E., Damon, A., Benton, R.S., and Patt, D.I. Human Body Size in Military Aircraft and Personal Equipment), the author selected body dimensions necessary in seat design and plotted them against stature. Some of the data he presents pertain to women pilots, as well as males. By utilizing these data, the author determined a comfortable supporting surface for passengers in a fixed seat. He recommends his proposed configuration as providing optimum comfort for 90 per cent of the American traveling public. The figures below illustrates his dimensional recommendations.

	Length Inches	Angle	
AB	**16 7/8**	**BCD**	**172°**
BC	**12**	**CDH**	**8°**
CD	**6**	**DEF**	**170°**
DE	**13**	**EFG**	**172½°**
EF	**11**	**CDE**	**105±2°**
FG	**10**		

The foot rest should be adjustable through an angle between 26° and 48° from the horizontal and through a distance from 28 to 33 inches forward of the projection of point D upon the floor.

Arm rest height 7¼" to 9" above a line between B and D.
Arm rest length 13" to 18".
Seat width 19" minimum, which will accommodate 95% of shoulder width and hip breadth of 95+% of traveling public.

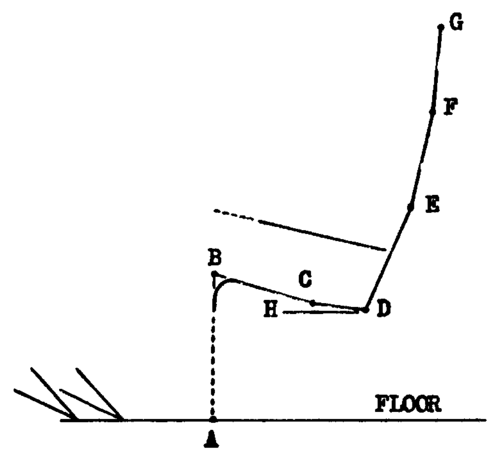


FIGURE 119 - 1

Comfortable supporting surface for passenger in fixed seat

With respect to cushions for seats in airplanes, the author states that cushioning must accommodate both gust loads and floor vibration. He advises against shock mounting of aircraft seats, because "the passenger on the cushion and the seat on the shock mount constitute a system having two degrees of freedom." The author is emphatic in his recommendation of cushion ventilation.

The article consists of three pages, including three illustrative figures. No bibliography, other then the one reference noted above, accompanies the text. A footnote states that the article is a condensation of a Douglas Aircraft Company report, for which no reference is given.

120. Moss, F.A. Measurement of Comfort in Automobile Riding. Society of Automotive Engineers, Transactions, Volume 25, 1930, pp. 7-12.

"Experiments that have been in progress since the 1929 Semi-Annual Meeting to measure the fatigue caused by an automobile ride using the human body as a measuring instrument, and to predict therefrom the possible effects of various types of spring-suspension, shock-absorber and other comfort-giving components are described. Initially, the problem was approached from the physiological standpoint because fatigue is definitely known to be a physiological phenomenon and, if the physiological changes are sufficiently marked to be measured, physiological tests are definite and quantitative."

"Changes in the human body are a good index of relative comfort, and, if the normal reactions of an individual or any group of individuals before a test are known, similar measurements at the end of a test or at the end of an automobile ride should show an appreciable difference. This difference, which the author claims is a direct measure of comfort, can be determined by measuring physical and nervous fatigue. For measuring the latter, number checking, speed of reaction, mental multiplication, steadiness of the hand and basal-metabolism rate tests were given; and, for the former, equilibrium tests using a wabblemeter were employed. Description of various types of wabblemeter are included, and the results of the nervous-fatigue tests are presented."

"The summarized conclusions are:

(1) Muscular fatigue, produced by strenuous exercise over a short period, can be well measured by physiological tests of blood, metabolism and urine.
(2) Of the physiological tests applicable to the fatigue of automobile riding, basal metabolism and carbon-dioxide combining-power of the blood are the most reliable.
(3) The fatigue from automobile riding is probably more nerve than muscle fatigue.
(4) Equilibrium, as measured by two differently recording wabblemeters, is markedly disturbed by long automobile riding. Other tests for nerve fatigue that have shown some differentiating value are number checking and mental multiplication.
(5) In fatigue produced over a long time, as by riding, fatigue counteractants, such as adrenalin, poured forth into the body seem to reduce the physiological manifestations."

"Plans for future development and study include (a) further improvement and standardization of two types of wabblemeter, (b) further standardization of the basal-metabolism test with particular attention to establishing a normal for different times of day, (c) improvement of the score card for reporting discomfort after the riding tests and (d) experiments with other new measuring devices. Further experimentation will include (a) investigation and application of tests to subjects in the laboratory, (b) study of tests on a large number of taxicab and motorcoach drivers and (c) application of the results with various outside groups of riders and test persons."

No answers to the "comfort" problem are given; the article is concerned solely with research technique.

Additional reference: Moss, F.A. Bodily Steadiness - A Riding-Comfort Index. Society of Automotive Engineers, Transactions, Volume 25, 1930, pp. 13-17.

121. Randall, Francis E. Seat Comfort. Paper No. 46-F-11 (M971-'46) for presentation at the Fall Meeting of the American Society of Mechanical Engineers, Boston, Massachusetts, 30 September - 3 October 1946.

The author discusses some of the factors making for comfort in aircraft seating and describes the work of W.E. Lay and L.C. Fisher, Department of Engineering Research, University of Michigan, in developing a Universal Test Seat as a measuring instrument.

The paper is seven pages long and includes two tables and one figure, which are included herein. There is no bibliography.

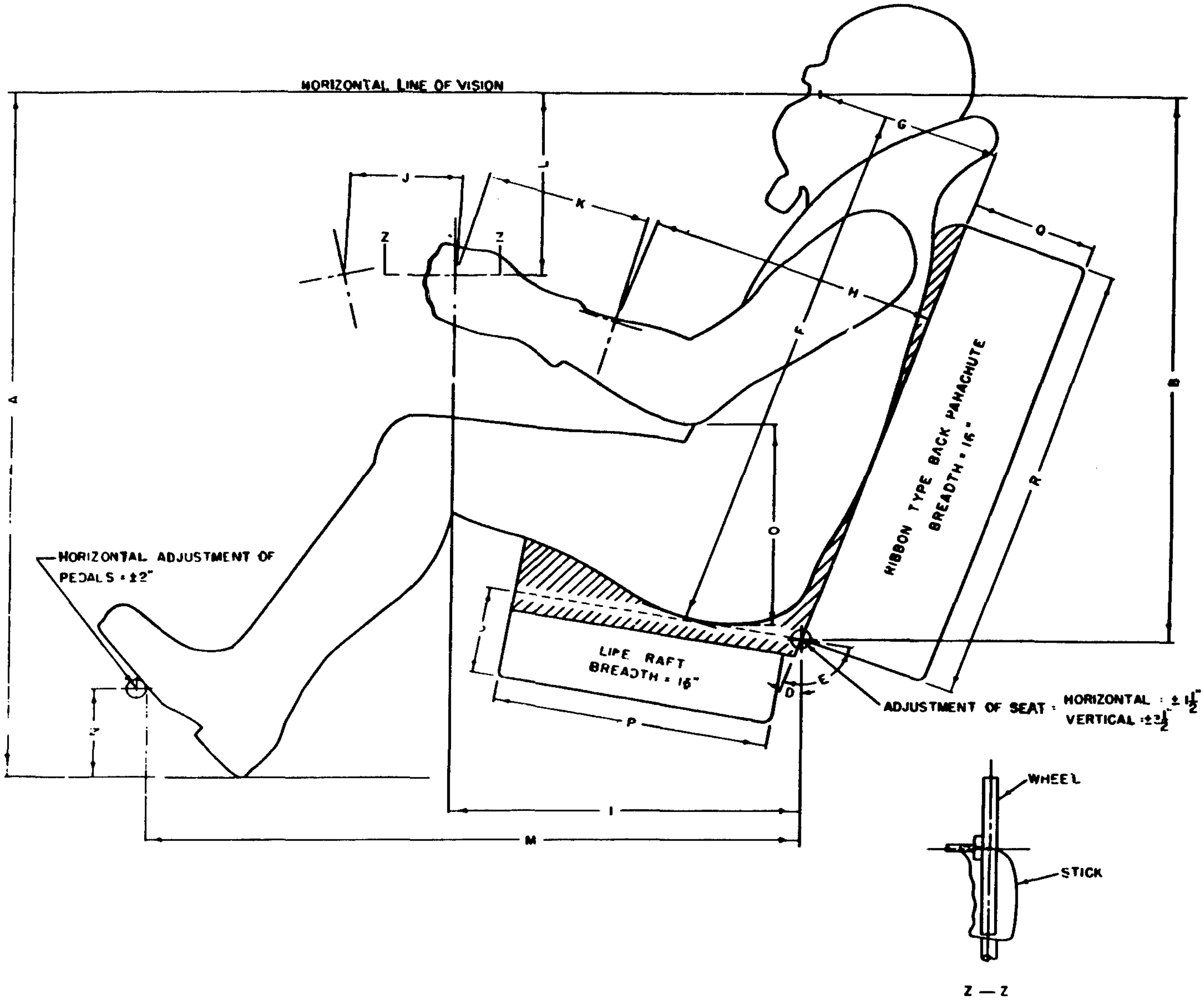


TABLE I - WHEEL TYPE CONTROL
(ALL VALUES IN INCHES UNLESS OTHERWISE NOTED)

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
37	$30\frac{1}{4}$	5	21°	101°	$29\frac{3}{4}$	10	$16\frac{5}{8}$	19	6	9	10	36	5	$9\frac{1}{4}$	15	7	25
39	$30\frac{3}{4}$	5	19°	101°	$30\frac{1}{4}$	$9\frac{3}{4}$	$15\frac{3}{4}$	19	6	9	$10\frac{1}{2}$	35	5	$9\frac{1}{4}$	15	7	25
41	$31\frac{1}{2}$	5	16°	101°	31	$9\frac{3}{4}$	$15\frac{1}{8}$	19	6	9	$10\frac{3}{4}$	$34\frac{1}{2}$	5	$9\frac{1}{4}$	15	7	25
43	$31\frac{3}{4}$	5	16°	101°	$31\frac{1}{4}$	10	$15\frac{1}{8}$	19	6	9	11	$34\frac{1}{2}$	5	$9\frac{1}{4}$	15	7	25

TABLE II - STICK TYPE CONTROL
(ALL VALUES IN INCHES UNLESS OTHERWISE NOTED)

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
37	$30\frac{1}{4}$	5	21°	101°	$29\frac{3}{4}$	10	$14\frac{1}{2}$	19	6	9	$11\frac{1}{2}$	36	5	$9\frac{1}{4}$	15	7	25
39	$30\frac{3}{4}$	5	19°	101°	$30\frac{1}{4}$	$9\frac{3}{4}$	$13\frac{3}{4}$	19	6	9	$13\frac{3}{4}$	35	5	$9\frac{1}{4}$	15	7	25
41	$31\frac{1}{2}$	5	16°	101°	31	$9\frac{3}{4}$	$13\frac{1}{2}$	19	6	9	$15\frac{1}{2}$	$34\frac{1}{2}$	5	$9\frac{1}{4}$	15	7	25
43	$31\frac{3}{4}$	5	16°	101°	$31\frac{1}{4}$	10	13	19	6	9	$17\frac{1}{2}$	$34\frac{1}{2}$	5	$9\frac{1}{4}$	15	7	25

FIGURE 121 - 1

Human Dimensional Requirements in Aircraft Cockpits

ADDITIONAL REFERENCES

122. Anon. Hooton's Chair. Life Magazine, February 11, 1946, pp. 33-36.

123. Baldwin, B.T. The Use and Abuse of Weight-Height-Age Tables as Indexes of Health and Nutrition. Journal of the American Medical Association, Volume 82, No. 1, 5 January 1924 and American Journal of Physical Anthropology, Volume 8, No. 1, (January-March) 1925.

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APPENDIX I

SEAT COMFORT

H.T.E. Hertzberg

In the field of Human Engineering probably no topic is more controversial than "seat comfort." There is no doubt that bus and truck drivers, airplane pilots, locomotive engineers, and others who must work long hours while seated, are deeply concerned with the comfort of their seats, and many are highly vocal about their dissatisfactions. In this subjective field each man understandably considers himself an expert on comfort, so that opinions "throng and clash, and neatly equal the commentators in number."

Seats are engineering structures and hence must be designed with respect to size, shape, strength, material, etc. In the past, few designers have seriously considered the provision of comfort to be an important part of their designs. Since World War II, however, it has been widely recognized that discomfort and fatigue make a man inefficient and more prone to mistakes. When such mistakes cause the loss of airplanes, trained crews, and cargo, the economic aspects of discomfort cannot be ignored. Hence the Air Force has actively sought to reduce the discomfort of its aircrew accommodations, especially in seating.

No one has evolved an engineering formula for this problem, but there are ways of getting answers. Some investigators, like Akerblom* have taken a theoretical approach by studying the anatomical structure of man. Others, including Moss (120), Lay and Fisher (118), Darcus (114), Henry**, Randall, Damon, et al. (12), and Hertzberg have utilized the more pragmatic method of "comfort-testing" the responses of a sample of subjects. During World War II, Randall and his group of anthropologists carried out extensive tests at Wright Field to ascertain the optimal arrangement of the pilot's seat and controls in aircraft cockpits. Because people are studied in both approaches, one might expect some comparability in results.

The trouble is that different conclusions have been reached by different investigators. Akerblom and Darcus, for example, have concluded that a flat, hard surface is the best seat; others, including the editor, contend that a properly contoured surface with some cushioning produces the least discomfort among conventional types of seating, over relatively long periods of time.

In any discussion of the subjective factors involved in bodily comfort, one must be clear about one's terminology and conceptions of "comfort." The editor thinks in the following terms.

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*Akerblom, B. Standing and Sitting Posture, with Special Reference to the Construction of Chairs. Nordiska Bokhandeln. Stockholm, Sweden, 1948

**Henry, J.P. A Method for the Assessment of Seat Comfort---National Research Council---#489

a. Although we tend to speak of comfort and discomfort as if they were two states of consciousness, for testing purposes it is more realistic to consider that there is only one, discomfort, and that "comfort" is only the absence of discomfort, just as cold is the absence of heat. It is the neutral sensory condition. Thus one cannot "provide comfort" in a seat design, one can only "eliminate sources of discomfort." In this sense of comfort, the implication of euphoria or active pleasure is ignored.

b. Until more objective methods are developed, the length of time that a sample of subjects can endure a given position is so far the simplest, though not the only way of assessing the discomfort resulting from it.

c. All words used to describe the quality of a seat or the degree of bodily discomfort ("good," "bad," "better," "mild," "severe," etc.) are relative, the only theoretical absolute being the state of "zero discomfort," i.e., the absence of pain.

d. Before one can say that a given seat or body support is "better" or "worse" than another, one must specify the expected duration of occupancy. What is "good" for two hours may be "bad" for four hours, and so on.

The rationale of comfort-testing is simple and direct. You put a sampling of persons into a given seating situation and measure the time they are willing to endure the position. Comparative opinions are usually solicited from the subjects. If the sample is large enough, one can assess the relative discomfort of any position with respect to another. Even if only one position is tested, the subjects can compare their immediate sensations with memories of previous experiences, and so provide gross judgments of "better" or "worse." Although it cannot be trusted too far, this method may save much time in early stages of development work.

There are some refinements of this general method which may be mentioned here. In 1948 a graphical means of assessing discomfort* was introduced. The horizontal scale marked time in hours, and the vertical scale used words indicating an ascending degree of discomfort, as follows: "slight, moderate, severe, unbearable" (the graph base-line was taken as zero discomfort). In this study each subject was asked to sit upon a commercial cushion for a maximum of eight hours, and to indicate the degree of his sensations on the graph as the hours passed. The subject could quit the test any time he judged his discomfort to be "unbearable." Of course, this was crude, as each person's response depended on many factors, such as his interpretation of the meaning of the words; his size, which governed the load on his tissues; the sensitivity of his own sensory system, and his willingness to admit pain; nevertheless, it gave interesting and informative individual curves definitely tending in the same direction. This study, like most studies conducted up to that time, did not use the same test-sample on a different type of seat to provide a comparison.

To remedy this situation, the editor planned a set of experiments designed to yield comparative data. In this way different seats could be rated not

*Hertzberg, H.T.E. AF Memo. Report MCREXD 695-82, Comfort Tests of the Pulsating Seat Comfort and Lumbar Pad, April 1949 merely with respect to time, but also according to known seat configurations graded by size, angulation, curvature, and hardness of seat pan and seat back. Different types of cushions could also be tested in standard conditions.

Because most seat tests in Anthropology Section were made for aircraft application, the tests started with a basic wooden mockup of a standard fighter seat: seat and back 17 inches wide, seat at 6° above horizontal, back at 13° past vertical, seat reference point supported 8.5 inches above the heel rest (floor). The seat pan and back were made flat. This was to be the standard reference configuration, all others to be rated relative to it. It was also intended as a standard test-seat for the many cushions submitted to the Air Force. Each subject would first make out a comfort graph for it. Also planned were repeated tests to investigate the reliability of such a standard. If found to be reasonably reliable, the basic configuration would then be modified in various ways, some of which follow:

a. Basic flat, hard seat, 1" foam rubber sheet.

b. Basic flat, hard seat, 2" foam rubber sheet.

c. Contoured metal seating surface, no cushion (produced by fixing a contoured metal seat pan in place at the proper angle, and raising the subject's heel rest level so that it remained 8.5 inches below Seat Reference Point [the theoretical intersection of the seat pan and seat back]).

d. Contoured metal seating surface, 1-inch cushion.

e. Contoured metal seating surface, 2-inch cushion.

By thus varying the seating conditions and using the subjects at intervals of several days, to insure the minimum carry-over of experience, it appeared possible to evolve a seating configuration that would support the subjects with little or no discomfort for as much as eight hours.

Tests were started, but they were naturally very time-consuming, and they were never completed as planned. Design studies on cushions were being carried on at the same time in Anthropology Section, both static (contoured foam rubber for a contoured metal pan) and pneumatic. Both succeeded extremely well, so that to all intents and purposes the question of seat configuration was settled, at least in the editor's* mind. A brief story of that development is told elsewhere.* It was found, however, in preliminary tests that the standard seat made the test subjects uncomfortable in about 1-1/2 to 2 hours, the contoured seat with 1 inch rubber pad in about 4-5 hours. The contoured seat pan with a contoured rubber cushion (USAF type MC-1) was used by every pilot in a flight of F-84's from United States to England--a 15-hour trip--and the pilots were enthusiastic about it. "Best cushion we've ever used," was the general comment.

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*Hertzberg, H.T.E. Some Contributions of Applied Physical Anthropology to Human Engineering. Annals of the New York Academy of Sciences, Vol. 63, Art. 4, November 1956

On such evidence, statistically inconclusive though it be, at present the editor is of the opinion that the adequately-cushioned, contoured seat is superior to a flat surface for persons who cannot frequently leave the seat. The argument advanced by many persons, that one can more easily shift from one buttock to the other on a flat surface than on a contoured surface, is true; but it involves the assumption that the buttock thereby relieved of pressure will completely recover during the period of relief. This is not substantiated in Anthropology Section tests. Experience has shown that shifting the weight does afford brief relief, but there is not a complete recovery, if only because one buttock must carry a double load while the other carries none; and the net result, over a period of hours, is a slowly increasing discomfort throughout the test. It has been found (unpublished data in Anthropology Section) that individual buttock loads may rise as high as 70 pounds per square inch on tall subjects with spare gluteal flesh. In any buttock type, however, it is the flesh immediately below the ischial tuberosities of the pelvis which must carry the sitting person's load. On a flat surface the load is concentrated, with little or no support from surrounding tissues; whereas in a contoured surface, especially with cushion, the tissues surrounding the tuberosities absorb an appreciable portion of the load, thereby reducing the discomfort in the compressed tissues. Experience with both the static and dynamic cushions (used during the 56-hour sitting tests at Wright Field) indicate that if a person's buttock pressures can be kept below a certain critical level, he can sit almost indefinitely without undue discomfort.

Although an extensive further survey of seating seems out of the question at present in the Air Force, the editor still would like to see the program carried on by others. A good many questions and ideas crop up. What other objective physiological means can there be to measure discomfort? Will a wobble-meter provide reliable results? Tapping nerves with slender electrical probes? Taking the pain responses from the person's nerve-paths by means of induction? Brain waves? What happens to the cells in the buttocks of cowboys who spend hours in the saddle? Aside from the maintenance of blood flow in his tissues by the oscillation of riding, do his buttock cells develop immunity to pressure? It would seem that much research could be envisioned for these and other objectives in the field of "comfort" that might well ease the discomfort and increase the efficiency of millions. It may be mentioned that Tufts University has recently issued a study* utilizing some of the basic techniques mentioned above. In past years, moreover, several commercial research laboratories have entered the field. In addition, there is considerable experimentation underway with cushions of the new plastic foams, some of which are promising. One may look hopefully to significant advances in this art that touches everyone of us.

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*Slechta, R.F., Wade, E.A., Carter, W.K., Forrest, J. Comparative Evaluation of Aircraft Seating Accommodations," WADC TR 57-136.

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13. ABSTRACT

This volume contains condensations of 121 reports in the field of Applied Physical Anthropology. A majority of the annotations are grouped under three headings, Anthropometry, Biomechanics, and Comfort: a few are included in a General Group. Working data and important illustrations are quoted directly from the original papers in most cases. A complete index is arranged by author as well as by subject. An additional list of reports (not annotated) is included as background material. Two appendices containing relevant commentary on Seating Comfort and Anthropomorphic Dummies, are also included.

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